

Missouri Action Options for Reducing Greenhouse Gas Emissions

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Table of Contents

Table of Contents

<i>Acknowledgments</i>	<i>i</i>
<i>List of Tables and Charts</i>	<i>v</i>
 <i>Chapter 1 – Introduction and Executive Summary</i>	
Introduction	5
Summary of Policy Options to Reduce Greenhouse Gases	7
Electric Generation	7
Residential and Commercial Buildings	9
Transportation	10
Agriculture and Forestry	11
Solid Waste Management	12
Achieving Multiple Benefits Through Harmonized Environmental Policy	14
Development of Project Priorities	15
Appendix 1 -- Methodology for GHG Emissions Estimates and Inventory	19
Appendix 2 – Emissions of Criteria Pollutants from Energy Use in Missouri	23
Estimated CO ₂ Emissions from Energy Use in Missouri, 1990-1999, by Sector	24
 <i>Chapter 2 – Options to Reduce GHG Emissions from Electric Generation In Missouri</i>	
Background	29
Technical Options – Centralized Generation	34
Advanced Technologies for Centralized Generation from Fossil Fuels...	34
Generation from Renewable Resources	39
Technical Options – Distributed Generation	43
Advanced Technologies for Distributed Generation from Fossil Fuels	45
Generation from Renewable Resources	47
Policy Options to Reduce CO ₂ Emissions from Electric Generation in Missouri	49
Promote Utility Choice of Clean and Efficient Centralized Generation Technologies	49
Promote Distributed Generation Options	52
Promote Availability and Adoption of Cost-Effective Renewable Generation Options	56
Appendix 1 – DG Resources Sited in Missouri	60
Appendix 2 – Estimated Volume and Energy Content of Biomass and Municipal Solid Waste Resources in Missouri	63

Chapter 3 – Options to Reduce GHG Emissions from Residential and Commercial Buildings in Missouri

Background	69
Technical Potential for Reductions	80
Residential Sector	81
Commercial Sector	82
Technical Potential Versus Achievable Potential	83
End Uses with Greatest Technical Potential for Reductions	84
Advanced Building Technologies	85
Policy Options	86
Energy Information and Education	88
Standards and Codes	90
Federal Appliance Standards and Energy Labels	90
Building Energy Codes	92
Voluntary Programs and Partnerships – Public Buildings	96
Energy Efficiency in State Facilities	96
Programs and Partnerships to Promote EE/RE in Other Public Buildings	99
Voluntary Programs and Partnerships – Residential Buildings	103
Low-Income Weatherization	103
Incentive Programs	109

Chapter 4 – Options to Reduce GHG Emissions from the Transportation Sector in Missouri

Background	123
Technical Options to Reduce GHG Emissions from Highway Travel in Missouri	126
Highway Infrastructure and Use	127
Four Areas of Technical Opportunity	129
Vehicle Technology	131
Fuel Economy	131
Alternative Fuel Vehicles	133
Potential Leverage Points for State Influence on Vehicle Technology	138
Vehicle Management	144
Improved Driving Behavior	144
Improved Vehicle Maintenance	145
Public Fleet Management	146
Infrastructure Management and Alternative Modes of Transportation	146
Advanced Highway Management	147
Improved Availability and Attractiveness of Alternatives to Single-Occupant Vehicle (SOV) Trips	151
Alternative Modes for Intercity Travel	152

Alternative Modes for Commuting and Local Travel	153
Promoting Multi-Modal Connectivity of Alternative Transportation Modes	156
Travel Needs and Planning	157
Trip Planning at the Personal Level	158
Transportation Needs Planning at the Institutional Level	159
Telecommuting	159
Teleconferencing	159
Technical Options to Reduce GHG Emissions from Freight Transportation in Missouri	161
Freight Transportation Infrastructure and Use	161
Areas of Technical Opportunity	163
Advanced Highway Freight Technology	164
Advanced Freight Pipelines	164
Intermodal Coordination of Freight Movement	165
Policy Options to Reduce Greenhouse Gas Emissions from Missouri's Transportation Sector	166
Public Information	168
Promote Highway Fuel Efficiency	168
Promote Highway Alternative and Renewable Fuel Use	171
Support Reduced Travel Needs and a Variety of Efficiency Travel Modes	175

Chapter 5 – Options to Reduce GHG Emissions from the Agriculture and Forestry Sectors in Missouri

Background	181
Greenhouse Gas Emissions and Sequestration from Missouri's Agricultural and Forestry Sectors	182
Methane (CH ₄) Emissions from Agriculture	183
Nitrous Oxide (N ₂ O) Emissions from Agriculture	185
CO ₂ Emissions from Agriculture and Land Use Changes	186
CO ₂ Emissions from Energy Use in Agriculture	187
CO ₂ Emissions from Land Use Changes	188
Agriculture and Forestry Sector Technical Options to Reduce or Sequester Greenhouse Gas Emissions in Missouri	190
Opportunities to Reduce GHG Emissions from Missouri's Agricultural Sector	190
Opportunities to Reduce Methane Emissions	191
Opportunities to Reduce Nitrous Oxide Emissions	194
Opportunities to Reduce Carbon Dioxide Emissions Through Increased Energy Efficiency	196
Opportunities to Reduce GHG Emissions Through Renewable Energy Development in Missouri's Agricultural and Forestry Sectors	201

Opportunities for Using Biomass from Missouri Farms and Forests	202
Opportunities for Farm-Based Wind Generation	207
Opportunities for Farm-Based Solar Energy Use	210
Opportunities to Offset GHG Emissions by Sequestering Carbon in Missouri Forests and Agricultural Soil	212
Agriculture and Forestry Sector Policy Options to Reduce or Sequester Greenhouse Gas Emissions in Missouri	223
Agriculture	223
Promote Use of Biomass, Wind and Other Farm-Based Renewable Energy	223
Promote Efficient Farm-Based Energy Use	227
Support Good Agricultural Management Practices that Reduce GHG Emissions	227
Promote Carbon Sequestration Programs and Practices	228
Forestry	230
Integrate Increased Carbon Sequestration and Sustainable Forestry Goals	231
Demonstrate Desirable Forest and Natural Landscape Management Practices on State-Owned Land	231
Encourage and Support Sustainable Forestry Practices by Private Landowners in Missouri	232
Expand Tree Planting and Other Land Cover on Missouri's Non-Forest Land	237
Monitor and Assess the Success of Voluntary Programs	239

Chapter 6 – Options to Reduce GHG Emissions from Solid Waste Management in Missouri

Background	249
Technical Options to Reduce or Sequester Greenhouse Gases Through Solid Waste Management in Missouri	250
Introduction	250
Source Reduction	250
Recycling	251
Landfill Gas Collection	256
Municipal Waste Combustion	257
Policy Options to Reduce or Sequester Greenhouse Gases Through Solid Waste Management in Missouri	257
Public Information and Education	257
Promote Source Reduction, Recycling and Reuse, Assigning Highest Priority to These Policy Options	258
Encourage Economically Sustainable Capture and Use of Methane Gas in Missouri Landfills	262
Consider Waste Combustion, Assigning Lesser Priority to This Option	263

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List of Tables and Charts

List of Tables and Charts

Chapter 1 – Introduction and Executive Summary

Appendix 1 – Emissions of Criteria Pollutants from Energy Use in Missouri

Chapter 2 – Options to Reduce GHG Emissions from Electric Generation in Missouri

Table 1 – Generation, Energy Use and CO₂ Emissions in Missouri Power Plants, 1999

Table 2 – CO₂, NO_x and SO₂ Emissions Reported by Missouri Power Plants Participating in EPA's Acid Rain Program, 1999

Table 3 – Comparison of Wind Generation Potential in Missouri to Iowa and Kansas

Appendix 1 – DG Resources Sited in Missouri

Chapter 3 – Options to Reduce GHG Emissions from Residential and Commercial Buildings in Missouri

Table 1a – Energy Consumption in Missouri's Residential and Commercial Buildings Sector

Table 1b – Projected Electricity and Natural Gas Use in Missouri Buildings Through 2020 Assuming "Business-as-Usual"

Table 2 – Historic and Projected CO₂ Emissions from Natural Gas Use in Missouri Buildings

Table 3 – Historic and Projected CO₂ Emissions from Electricity Use in Missouri Buildings

Table 4 – Projected Increases in CO₂ Emissions Under "Business-as-Usual" Through 2020

Table 5 – Missouri Electricity Use, 1998 and 1999

Table 6 – Estimated Emissions of Criteria Pollutants from Missouri Fossil Fuel Use in Residential Buildings, Commercial Buildings and Other Sectors

Table 7 – CO₂, NO_x and SO₂ Emissions Attributed to Electricity Use in Missouri Buildings

Table 8 – Estimated End Use Share of Electricity Consumption in Residential Buildings, 1990-2020

Table 9 – Residential CO₂ Emissions – Projected “Business-as-Usual” Emissions and Impact of Achieving 5-Lab “Technoeconomic Potential” for Reductions

Table 10 – Commercial CO₂ Emissions – Projected “Business-as-Usual” Emissions and Impact of Achieving 5-Lab “Technoeconomic Potential” for Reductions

Table 11 – Estimated Percentage of “Technoeconomic Potential” for Energy Efficiency That Could be Achieved in the Building Sectors by Implementing the “Moderate” and “Advanced” Scenarios through 2010 and 2020

Table 12 – Projected Increase Through 2010 in Missouri Residential Building CO₂ Emissions (thousand tons) from Electric and Natural Gas Use Under Business-as-Usual and Three Efficiency Scenarios

Table 13 – Projected Increase Through 2020 in Missouri Residential Building CO₂ Emissions (thousand tons) from Electricity and Natural Gas use Under Business-as-Usual and Three Efficiency Scenarios

Table 14 – Percentage Increase in Missouri Residential CO₂ Emissions Under 5-Lab Study Scenarios, Compared to Business-as-Usual Reductions

Table 15 – Projected Increase Through 2010 in Missouri Commercial Building CO₂ Emissions (thousand tons) from Electricity and Natural Gas Use Under Business-as-Usual and Three Efficiency Scenarios

Table 16 – Projected Increase Through 2020 in Missouri Commercial Building CO₂ Emissions (thousand tons) from Electricity and Natural Gas Use Under Business-as-Usual and Three Efficiency Scenarios

Table 17a – EIA 5-Lab and AEO 2001 Estimates of Technical Potential to Reduce Projected Business-as-Usual Residential Electricity Consumption Through Efficiency, by End Use Sector

Table 17b – Projected Reduction (Percentage) and Growth Rate Comparison for 5-Lab and EIA Efficiency Scenarios Compared to Residential Business-as-Usual Projects from Table 17a

Chapter 4 – Options to Reduce GHG Emissions from the Transportation Sector in Missouri

Chart 1 – Missouri Consumption of Transportation Fuels, 1990-1999

Table 1a – Increase in CO₂ Emissions from Three Major Transportation Fuels, 1990-1999

Table 1b – Transportation-related CO, NO_x and VOC emissions in Missouri, 1990-99

Table 2 – Fuel Economy (mpg) of New Automobiles Sold in United States, 1976-2000

Table 3 – EIA Estimates of AFVs in Use in Missouri in 1999

Table 4 – Estimated Net GHG Reductions from Ethanol Use in Vehicles

Table 5 – Estimated Net Full Fuel Cycle Energy Gains and GHG Reductions from Alternative Fuel and Advanced Technology Use in Vehicles

Table 6 – Energy Intensity (Btu per passenger-mile) of Common Passenger Travel Modes

Table 7 – Funds Required to Meet Missouri’s Statewide Public Transportation Need (in millions)

Chapter 5 – Options to Reduce GHG Emissions from the Agriculture and Forestry Sectors in Missouri

Table 1 – Estimated and Projected Methane Emissions from Swine and Cattle Operations, 1990-2015 (tons)

Table 2 – Nitrogenous Fertilizer Use in Missouri, 1989-2000

Table 3 – Estimated Energy Consumption in U.S. Agriculture, 2000

Table 4 – Comparison of Some Typical Farm Home Heat Requirements and the Number of Animals Needed to Meet These Requirements

Table 5 – Confined Swine Feeding Operations and Lagoons in Missouri

Table 6 – Estimated Carbon Sequestration by Missouri Forests, 1990-1996

Table 7 – Estimated Soil Carbon Sequestration from Selected “Best Management” Practices

Table 8 – Tillage Systems and Associated Carbon Sequestration Coefficients

Chart 1 – Missouri Cropland Acreage Planted Using Different Tillage Systems, 1989-2000

Chart 2a, b – Missouri Corn and Soy Acreage Planted Using Different Tillage Systems, 1989-2000

Chart 3 – Net Annual Carbon Sequestration from Missouri Tillage Systems, 1989-2000

Appendix 1 – U.S. Operating Anaerobic Methane Digesters by Digester Type

Chapter 6 – Options to Reduce GHG Emissions from Solid Waste Management in Missouri

Figure 1 – Recycling Collection Services in Missouri

Figure 2 – Impact of Recycling on GHG Reduction, Energy Use and Energy Cost

Figure 3 – Yard Waste Collection Services in Missouri

Appendix 1 – Estimated Reductions in Missouri Greenhouse Gas Emissions from Recycling

Missouri Action Options for Reducing Greenhouse Gas Emissions – July 2002

Chapter 1

Introduction and Executive Summary

Chapter 1: Introduction and Executive Summary

Introduction.....	5
Summary of Policy Options to Reduce Greenhouse Gases.....	7
Electric Generation	7
Residential and Commercial Buildings	9
Transportation	10
Agriculture and Forestry	11
Solid Waste Management	12
Achieving Multiple Benefits Through Harmonized Environmental Policy.....	14
Development of Project Priorities	15
Appendix 1 – Methodology for GHG Emissions Estimates and Inventory.....	19
Appendix 2 – Emissions of Criteria Pollutants from Energy Use in Missouri	23
Estimated CO ₂ Emissions from Energy Use in Missouri, 1990-1999, by Sector	24

Chapter 1 – Introduction and Executive Summary

Introduction

In 1991, the Missouri Commission on Global Climate Change and Ozone Depletion, concluded after extensive study and numerous hearings that “...climate change is now being induced by human activity and may occur at an unprecedented pace which could challenge natural and human adaptation. Whether significant change occurs by 2030, 2050, or some other year, continued accumulation of greenhouse gases will alter the environment.” A scientific assessment of the potential impact of climate change on Missouri is outside the scope of this report.

Missouri recognizes that if global warming occurs, it could have adverse consequences for Missouri's citizens and economy. In 1994, Missouri began two projects addressing global warming. The first “Phase 1” project inventoried statewide GHG emissions for the 1990 baseline year and was completed in 1996. The second “Phase 2” project assessed GHG emission trends, projected future statewide GHG emissions and with this final report identifies and analyzes options for reducing the state's contribution to global GHG emissions. The Missouri Department of Natural Resources' Energy Center developed these reports with input from multiple stakeholders. The projects received partial funding from the U.S. Environmental Protection Agency. Both the Phase 1 and Phase 2 projects have adhered to U.S. EPA project guidelines. (see Appendix 1)

Action Options for Reducing Missouri Greenhouse Gas Emissions analyzes options to reduce statewide greenhouse gas (GHG) emissions in five key sectors: electric generation (Chapter 2); building energy use (Chapter 3); highway and other transportation (Chapter 4); agriculture and forestry (Chapter 5); and solid waste management (Chapter 6). It is the third and last of three reports developed and released by Missouri's Phase 1 and Phase 2 GHG projects. The report draws on several previous state reports that are referenced throughout this document.

Predecessor reports include:

- The final report (1991) of the Missouri Commission on Global Climate Change and Ozone Depletion. The Commission was established by concurrent resolution of the Missouri legislature in 1989. State legislators, academics, business, environmental organizations and the departments of Natural Resources and Agriculture were represented on the Commission.
- The final report (1992) of the Statewide Energy Study, published by Missouri's Environmental Improvement and Energy Resources Authority (EIERA) in 1992. The Energy Study identified policy initiatives and action items to increase energy efficiency and sustainability in Missouri. For each measure proposed, the Study estimated payback, net job and income creation and reduction of CO₂ and SO₂. The Energy Study drew on an extensive public participation process as well as literature and technical review.
- The final report (1992) of the Department of Natural Resources' Institute Project. The project, with members from all department divisions, endorsed action recommendations from the Commission and the Statewide Energy Study and proposed pursuing a “no regrets”

climate change policy for Missouri. The Institute recommended that “this policy does not depend on the issue of whether global warming is a reality. A “no regrets” policy bases decisions upon collateral environmental benefits and sound economic principles. “...The state of Missouri has much to gain and little to lose in proceeding with a “no-regrets” approach.”

- Two previous reports from the U.S. EPA Phase 1 and Phase 2 GHG projects were issued in 1996 and 1990. The first report, a product of Missouri’s “Phase I” GHG project, developed a detailed inventory of anthropogenic (due to human sources) GHG emissions in Missouri for the “baseline” year of 1990.¹ The second GHG report, part of Missouri’s “Phase 2” GHG project, completed in 1999, estimated trends and projected future GHG emissions in Missouri.²

Climate Change and Missouri

During the decade since the Missouri Commission on Global Climate Change and Ozone Depletion released its report, thousands of climatologists and other earth systems scientists have conducted intensive research on climate change. Much of this work has been coordinated internationally through the Intergovernmental Panel on Climate Change (IPCC). The IPCC’s 3-volume Third Assessment Report of climate change issues published in 2001 represents the state-of-the-art.

A number of studies have attempted to assess the potential impact on the United States of climate change, including impact on such factors as human health; birds and other species; sectors such as agriculture, forestry and fisheries; natural resources such as water resources and wetlands; and regions such as polar regions, mountains, forests, deserts and coastal zones. These studies have indicated variable impact on different regions and the potential for both “losers” and “winners.” A U.S. EPA assessment of the impact of climate change in Missouri indicates potential for negative consequences on agriculture, water quality, human health and some plant and animal species.³ However, many of the potentially most important impacts depend on whether rainfall increases or decreases, which cannot be reliably projected for specific areas. In the United States generally, there is likely to be an overall trend toward increased precipitation and evaporation, more intense rainstorms, and drier soils. Scientific literature on climate change, including the Third Assessment Report, documents many uncertainties concerning climate change. There has been public debate concerning the policy implications of these uncertainties. The American Geophysical Union (AGU), a professional society of earth scientists, concluded in an official statement on climate change that:

¹ Missouri Department of Natural Resources, *Inventory of Missouri’s Estimated Greenhouse Gas Emissions in 1990, 1996*

² Missouri Department of Natural Resources, *Greenhouse Gas Emission Trends and Projections for Missouri, 1990-2015, 1996.*

³ U.S.EPA, *Climate Change and Missouri*,
<http://www.epa.gov/globalwarming/impacts/stateimp/missouri/index.html>

*Present understanding of the Earth's climate system provides a compelling basis for legitimate public concern over future global- and regional-scale changes resulting from increased concentrations of greenhouse gases... The present level of scientific uncertainty does not justify inaction in the mitigation of human-induced climate change and/or the adaptation to it... AGU recommends the development and evaluation of strategies such as emissions reduction, carbon sequestration, and adaptation to the impacts of climate change.*⁴

*The AGU statement does not include an estimate of the likely impact on climate. However, the IPCC's Third Assessment Report, published in 2001, concludes that "...in the light of new evidence and taking into account the remaining uncertainties, most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations...The rate of anthropogenic warming is likely to lie in the range 0.1 to 0.2°C/decade over the first half of the 21st century."*⁵

*A panel of the National Research Council's Committee on the Science of Climate Change, convened to respond to a White House request for an assessment of the IPCC report, responded that "...the IPCC's conclusion that most of the observed warming of the last 50 years is likely to have been due to the increase in greenhouse gas concentrations accurately reflects the current thinking of the scientific community on this issue...Despite the uncertainties, there is general agreement that the observed warming is real and particularly strong within the past 20 years."*⁶

Summary of Policy Options to Reduce Greenhouse Gases

The report focuses on action options to reduce GHG emissions from electric generation, residential and commercial buildings, transportation, agriculture, forestry and solid waste management. Chapters 2-6 of the report discuss technical and policy options for reducing GHG emissions from each of these sectors.

The "Policy Options" sections found in each chapter focus primarily on 'no-regrets' options that Missouri may wish to consider to reduce greenhouse gas emissions in the various sectors. The report does not make specific recommendations on which options should be pursued.

Electric Generation

The policy review section in Chapter 2 focuses on possible supply-side options to reduce CO₂ emissions from electric generation in Missouri. Electric generation, which in Missouri relies primarily on centralized coal-fired power plants, is the most important single source of GHG emissions in the state. In 1999, approximately 73.5 million tons of CO₂ were emitted by power plants, an increase of more than 20 million tons from this source in 1990. About 98 percent of these emissions were from coal-fired plants. Coal is a relatively abundant and inexpensive fuel source for power plants but it is also much more carbon intensive than other fuels.

⁴ Position statement, January 28, 1999

⁵ IPCC, 2001, Technical Summary and Chapter 12, Detection of Climate Change and Attribution of Causes. Uncertainties are discussed in Section 5 of Chapter 12.

⁶ NRC, Climate Change Science: An Analysis of Some Key Questions, 2001

Supply-side options to reduce CO₂ emissions from electric generation fall logically into one of the following strategies:

- Efficiency – Increase the efficiency with which fossil fuel is used to generate electricity.
- Fuel switching – Rather than coal, generate from a different fossil fuel energy source that contains less carbon.
- Renewables – Rather than fossil fuel, generate from a renewable energy source. In this report renewable energy sources are taken to include energy from wind, solar thermal energy, photovoltaic cells and panels, dedicated crops grown for energy production, organic waste biomass used for electricity production and low head hydropower.

Improvements in generating efficiency or a shift in generating source could be applied to centralized power plants or achieved by developing new, efficient on-site generation sources (“distributed generation”). “Distributed generation” includes (a) renewable technologies such as photovoltaic and wind and (b) technologies that can use either a renewable or fossil source of energy such as microturbines, small gas turbines, reciprocating engines and fuel cells.

The policy review emphasizes voluntary means for achieving these goals, including collaboration and incentives to encourage utilities to voluntarily install and maintain clean, efficient generating facilities and adopt cost-effective renewable generation options; options to promote and provide incentives for specific renewable technologies; and information and other assistance directed to end users and the general public. Within the context of an approach that emphasizes voluntary action and incentives, regulatory options are also presented for consideration

Promote Utility Choice of Clean and Efficient Centralized Generation Technologies

The review of policy options discusses opportunities for public/private collaboration and research promoting cleaner and more efficient generation in centralized power plants.

Promote the Availability To and Adoption by End-Users of Clean, Efficient Distributed Generation Technologies

- Develop output-based emission standards for all generators.
- Review utility exit fees for combined heat and power (CHP) and other self-generators.
- Establish consistent utility interconnect standards for CHP and other self-generators.
- Establish net metering for CHP and other self-generators.
- Streamline environmental permitting procedures for developers of new distributed generation facilities.
- Establish a generation source disclosure & labeling standard.
- Integrate renewable distributed generation into Supplemental Environmental Projects (SEPS) as an alternative to fines for environmental violators.

Promote Availability and Adoption of Cost-Effective Renewable Generation Options

- Promote and provide incentives for selected technologies.
- Establish rule to require utility renewable energy investment in generation.
- Establish a renewable portfolio standard for electricity retailers.
- Incorporate renewable generation into environmental regulations such as state implementation plans.
- Encourage or require each Missouri utility to offer a premium “green energy” package to its customers.
- Encourage or require the formulation of a Missouri “green energy” standard.

A systems benefits charge could be adopted as a funding mechanism to promote clean, efficient distributed generation technologies, renewable energy use in the electric utility and other sectors, and end-user energy efficiency.

As a cautionary note, adding new generation resources that incorporate new, less polluting technology could slow down increases of CO₂ emissions but is not likely to result in an absolute reduction of emissions from the utility sector. Absent a national policy decision that results in reduction of coal-fired generation, Missouri’s existing coal fleet will most likely remain in operation, with new generating technologies coming online mainly to serve new loads. Although technical options such as efficiency improvements and co-firing could reduce CO₂ emissions from coal-fired plants that remain in operation, the scope for these options are limited.

Residential and Commercial Buildings

Policy options to reduce CO₂ emissions from utilities (Chapter 2) and buildings (Chapter 3) are closely related. The single largest source of demand for electricity in Missouri is electricity use in buildings. Any plan to reduce GHG emissions must include complementary and coordinated supply-side and demand-side components, reducing the emissions associated with energy production – particularly electric generation – while simultaneously introducing technologies and incentives for energy consumers to use electricity and other energy sources more efficiently and with less waste. Thus, the policy review of options to reduce GHG emissions from buildings is complementary to the review of options to reduce GHG emissions from electric generation.

In addition to electricity use, natural gas is an important energy source for residential and commercial buildings in Missouri. Measured in absolute terms of British thermal units (Btu) consumed, building owners use more natural gas than electricity. However, in 1999, electricity use in buildings had about five times greater GHG impact (about 50 million tons of CO₂ emissions) than natural gas use (about 10 million tons).

The policy review section in Chapter 3 emphasizes energy information, voluntary programs and partnerships to promote the adoption of energy efficiency and renewable energy to public and residential buildings. Options that are discussed include:

- Improve the Energy Efficiency in State Facilities Program.
- Energy-efficient loans, education and partnerships with schools and local governments.

- Promote the adoption of energy efficiency and renewable energy in hospitals.
- Support federal appliance standards.
- Implement energy efficiency demand-side management programs.
- Support low-income residential efficiency programs.
- Support Home Energy Rating Systems.
- Support Energy Star labeling.
- State-Sponsored incentive programs for residential energy efficiency.

The policy review section also analyzes options related to energy codes. A number of states, but not Missouri, have adopted statewide building codes that have an energy codes component. Like federal appliance standards, energy codes are a highly cost-effective way to promote energy efficiency in the building sector. Codes and standards have two benefits: they assure that the public benefits from technological progress and they establish a benchmark for voluntary labeling programs such as Home Energy Rating Systems.

The policy review provides a historical perspective on the development of energy codes in Missouri and presents options for benefiting from energy codes even if a mandatory statewide code is not adopted.

Transportation

The policy review section in Chapter 4 focuses on options to reduce CO₂ emissions from highway vehicles burning motor gasoline or diesel fuel. Almost all greenhouse gas (GHG) emissions from Missouri's transportation sector are in the form of CO₂ from fossil fuel use. Any plan to reduce CO₂ emissions must include a transportation component since this sector accounts for about a third of Missouri's total CO₂ emissions from fossil fuel use, second only to the utility sector. Emissions from highway travel account for about 85 percent of the transportation sector's CO₂ emissions in Missouri.

Policies to reduce greenhouse gas emissions from highway vehicles can be classified into the following three categories:

- Policies whose objective is to increase vehicle efficiency, resulting in less fuel use and lower GHG emissions per mile traveled (vehicle efficiency).
- Policies whose objective is to shift vehicle owners from conventional to alternative and renewable fuel use, which may result in lower GHG and other emissions per Btu of fuel use.
- Policies whose general objective is to reduce the use of carbon-intensive transportation modes such as low-occupancy highway vehicles.

Promote the Fuel Efficiency of Highway Vehicles in Missouri

The policy review section analyzes options to:

- Strengthen state and local governments' visible leadership in promoting efficiency and renewable use in the transportation sector, starting with full compliance with existing statutory obligations.
- Encourage private sector vehicle owners to operate and maintain their vehicles for optimal fuel efficiency.

Promote Alternative and Renewable Fuel Use in Highway Vehicles in Missouri

The policy review section analyzes options to:

- Increase state and local government use of alternative and renewable fuels, including ethanol and biodiesel.
- Extend this public leadership into collaborative efforts with industry to create and support markets and infrastructure for alternative and renewable transportation fuels in Missouri.
- Encourage automakers to locate the manufacture of new generation highway vehicles, including hybrid and fuel cell vehicles, in Missouri.

Support Measures that Reduce the Need for Travel and Support a Variety of Efficient Methods for Travel in Missouri

The policy review section analyzes options to:

- Promote a transportation infrastructure that supports and encourages the use of multiple efficient modes of personal travel, business travel and freight transportation.
- Implement travel policies and procedures that reduce work-related travel by state employees.
- Encourage state employees with options to use energy efficient means of commuting to work.
- Incorporate voluntary emission reduction programs for mobile sources into State Implementation Plans (SIPs) for attaining air quality standards.

Agriculture and Forestry

Missouri's agricultural and forestry sectors have great potential to reduce or offset GHG emissions from other sectors of Missouri's economy. Missouri farmers and landowners could develop biomass, wind and other renewable energy resources from Missouri's agricultural and forested land. Other sectors of Missouri's economy could use electricity generated from wind or biomass and fuels such as ethanol and biodiesel produced from biomass resources, reducing the GHG emissions that would otherwise result from energy use in these sectors.

In addition, Missouri's agricultural sector is itself an important source of GHG emissions. Missouri's agricultural sector is the leading source of methane and nitrous oxide emissions due to human activities in Missouri. As an energy-intensive industry, agriculture is also a source of CO₂ emissions from energy use.

The agriculture sector policy review section in Chapter 5 focuses on options to:

- Promote generation and other cost-effective energy use from Missouri farm-based renewable resources including biomass and wind resources.
- Promote efficient energy use in farm residences and agricultural operations.
- Support good agricultural management practices that reduce greenhouse gas emissions.
- Expand participation in conservation and other federal programs that promote practices that contribute to greenhouse gas emission reductions and carbon sequestration in Missouri's agricultural sector.

The forest sector policy review section in Chapter 5 focuses on options to:

- Integrate the goals of increased carbon sequestration in Missouri's forestry sector with the goal of promoting sustainable forestry.
- Create opportunities to demonstrate desirable forest and natural landscape management practices on state-owned forested land.
- Encourage and support sustainable forestry practices by private landowners in Missouri.
- Expand tree planting and other land cover on Missouri's non-forest land.
- Monitor and assess the success of expanded education, training, technical assistance, demonstration, incentive and other voluntary programs in promoting sustainable management of Missouri forestlands.

Solid Waste Management

Missouri's municipal solid waste landfills are an important source for emissions of methane, a highly potent greenhouse gas. An estimated 6.3 million tons of methane was emitted from Missouri landfills in 1995. This is a midpoint estimate of emissions expressed in equivalent short tons of carbon dioxide. An estimated 5.2 million tons of methane are projected to be emitted from Missouri landfills in 2005.

Landfill methane also represents an alternative energy source that could reduce Missouri's dependence on imported fossil fuels and reduce CO₂ emissions from fossil fuel combustion. This section emphasizes options for reducing or sequestering GHG emissions from solid waste according to their position in the following hierarchy of solid waste management practices – source reduction (including reuse) the most preferred method, followed by recycling and composting, and, lastly, disposal in combustion facilities and landfills. Reducing the amount of solid waste generated that is destined for landfills is a primary goal of solid waste management programs in Missouri and should receive primary policy emphasis.

The policy review section in Chapter 6 focuses on options to:

- Continue to inform and educate state and local policy makers, students and the general public regarding opportunities and benefits for improving solid waste management in Missouri.

- Promote practices that reduce the creation of solid waste in Missouri and provide feasible alternatives to disposing of waste in landfills.
- Encourage economically sustainable collection of methane gas in Missouri landfills.
- Consider waste combustion as an approach to GHG reduction in Missouri, while assigning lesser priority to this option.

Emissions and Trends

This action options report was preceded by two reports that focused on assessing sources of GHG emissions in Missouri – the 1990 Inventory Report and the Trends and Projections (T&P) report.

The 1990 inventory report focuses on emissions inventories of four greenhouse gases – carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O) and perfluorocarbons (PFCs). In 1990, anthropogenic emissions of these four gases equaled approximately 148 million short tons carbon dioxide equivalent (STCDE). About 75 percent of these emissions (111 million tons) were CO₂ emissions from fossil fuel use. Of the four energy end-use sectors, the residential and commercial sectors accounted for a total of 47 percent of energy-related CO₂ emissions, followed by transportation with 34 percent and industry with 20 percent.

The T&P report estimates state GHG trends for 1990 to 1996 and projects emissions for 1996 to 2015. Key points include the following:

- *Between 1990 and 1996, gross emissions of the four greenhouse gases from all sources increased by about 20 million tons, from about 148 million STCDE to 168 million tons STCDE. In 1996, about 80 percent of gross GHG emissions (133 million tons) were CO₂ emissions from fossil fuel use. Among energy end-use sectors, the most rapid growth in energy-related CO₂ emissions was in the residential and commercial (buildings) sectors, followed by transportation.*
- *Methane emissions increased by nearly 2 million tons STCDE between 1990 and 1996, but this increase in methane emissions was more than offset by a decrease in PFC emissions of nearly 4 million tons STCDE. The reduction in PFC emissions was a one-time event due to improvements at Missouri single aluminum plant.*
- *Rather than provide a single estimate for future GHG emissions, the report provides a range of estimates based on different projection methods and scenarios. All projections assume “business as usual,” that is, no new policies to limit or reduce GHG emissions. The report projects future CO₂ emissions from fossil fuel combustion by utilities and other sectors; utility emissions are a major source of variability in the projections. The resulting projections for gross CO₂ emissions from energy use in 2015 range from 154 to 170 million tons, with several projections falling into a mid-range estimate of 161-163 million tons STCDE.*

- *The report also estimates GHG emissions from a variety of sources other than energy use. The chapter estimates that GHG emissions from some sources will decrease and others will increase between 1996 and 2015, but the total will be about the same in 2015 as in 1996, 34 to 35 million tons STCDE.*
- *In addition to these estimates of gross (pre-sequestration) GHG emissions, the report estimates net GHG emissions. The estimate of net emissions takes into account the effect of biomass growth in Missouri's forests, which cover nearly a third of the state, as well as land use changes. The net effect of this factor was to sequester about 20 million tons of carbon dioxide.*
- *The T&P report projects that annual carbon sequestration from forest biomass will decline over time, but discusses possible errors in the estimate due to limitations in the way that available models for estimating net sequestration deal with increased removal of forest products.*

The T&P report does not account for carbon sequestration in forest products or crop soils. Chapter 5 of this report includes an explanation of reasons for not estimating forest product sequestration and a preliminary estimate of cropland CO₂ sequestration that occurred during the 1990s as Missouri farmers adopted conservation tillage practices.

Achieving Multiple Benefits through Harmonized Environmental Policy

A no-regret approach relies on identifying ancillary environmental and economic benefits for GHG reduction options. This report identifies numerous ancillary benefits for the options presented. Examples of the benefits identified throughout the report include:

- Increased economic productivity from cost-effective implementation of energy efficiency and renewable energy and well-managed agricultural and forest land resources.
- Increased energy security and reduced vulnerability to price spikes or supply shortages through development of state renewable energy resources.
- Reduction in congestion and maintenance costs for infrastructure resources such as electric transmission and distribution, pipelines, highways and bridges.
- Improved environmental management including harmonized reduction of GHG and criteria pollutants.

The relationship between GHG mitigation and conventional air pollutant control requires additional comment. In continuing to address challenges for maintaining acceptable air and water quality standards, regulators have opportunities to obtain concurrent GHG emission reductions. With few exceptions, strategies that mitigate GHGs will also result in reduced emissions of other air pollutants.

The most widely recognized harmonized strategies relate to fossil-fuel combustion, the major source in Missouri of CO₂ emissions as well as PM, NO_x, SO₂, CO and air toxics. STAPPA/ALAPCO has demonstrated, through four detailed case studies of specific states or localities, that there is significant potential to simultaneously reduce GHG and criteria pollutants through “harmonized” measures, most of them focused on energy efficiency or renewable energy.⁷

Energy use is the primary source of emissions of three criteria pollutants in Missouri – accounting for more than 95 percent of statewide emissions of oxides of nitrogen (NO_x), 90 percent of carbon monoxide (CO), 75 percent of sulfur dioxide (SO₂) emissions and about 50 percent of emissions of volatile organic compounds (VOCs). Appendix 2 summarizes emissions of these four criteria pollutants from energy use in the utility, transportation and other sectors.

In recent years there has been widespread recognition in the environmental regulatory community of the need in all sectors to develop emission control strategies that reduce multiple pollutants and in particular to harmonize strategies for reducing criteria pollutants with strategies for reducing GHG emissions. Many control measures commonly considered for reductions of a specific criteria pollutant have little or no impact on other pollutants and particularly little or no impact on GHG emissions. The amount of CO₂ emitted from the combustion process is determined primarily by the quantity of carbon in the fuel. To date, researchers have not identified an economically viable technology to capture and sequester the relatively massive quantities of CO₂ that are emitted from combustion processes. Post-combustion controls for NO_x, and SO₂, such as selective catalytic or non-catalytic reduction strategies, are not capable of reducing CO₂ from the exhaust stream. Indeed, these technologies can increase GHG emissions by lowering plant or vehicle energy efficiency.

Therefore, wherever possible, control programs or incentives should be implemented that will minimize the combustion of fossil fuel.

State and local environmental officials in Missouri have a key role in environmental planning through development of rules, implementation plans and supplementary environmental projects and through their contacts with utility and industry stakeholders. The most effective means for harmonizing environmental quality and GHG emissions goals is to assign priority to strategies that achieve environmental quality goals and also provide GHG reduction benefits, rather than to strategies that are ineffective or counterproductive in controlling GHG emissions. This could be applied to efforts to effect emission reductions at government-owned facilities as well as the private sector.

Development of Project Priorities

The project’s analytic priorities were determined early in the project in consultation with a steering committee and a stakeholders’ meeting. The project steering committee, representing five divisions of the Department of Natural Resources, eight other state agencies and the University of Missouri-Columbia, met four times early in the project to determine the project’s

⁷ STAPPA/ALAPCO, Chapter 11

direction and set criteria for selection of action options to be included in the analysis. High priority was assigned to the following criteria: economic efficiency, ancillary benefits and costs, effectiveness in reducing greenhouse gas emissions, and political and institutional feasibility.

Project staff presented the steering committee with a draft list of possible state actions to reduce greenhouse gas emissions compiled from previous recommendations by the Missouri Commission on Global Climate Change (1991), the Missouri Statewide Energy Study (1992) and follow-up studies (1993), the Missouri Department of Transportation's long-range transportation plan (1995-96) and the Governor's Energy Futures Coalition (1994-96). Planning documents from other state and federal sources including U.S. EPA were also consulted in formulating the actions.

Steering Committee and Stakeholder Organizations

<i>AmerenUE</i>	<i>Missouri Dept. of Natural Resources</i>
<i>Associated Electric Cooperative, Inc.</i>	<i>Missouri Dept. of Transportation</i>
<i>Associated Industries of Missouri</i>	<i>Missouri Forest Products Assn.</i>
<i>Audubon Council of Missouri</i>	<i>Missouri Native Plant Society</i>
<i>Bridging the Gap</i>	<i>Missouri Office of Public Counsel</i>
<i>Central Electric Power Cooperative</i>	<i>Missouri Oil Council</i>
<i>Coalition for the Environment</i>	<i>Missouri Propane Gas Assn.</i>
<i>Heartland Renewable Energy Society</i>	<i>Missouri Public Service Commission</i>
<i>Kansas City Power and Light</i>	<i>Missouri Public Utility Alliance</i>
<i>Laclede Gas Company</i>	<i>National Biological Service</i>
<i>League of Women Voters of Missouri</i>	<i>Parkway School District</i>
<i>Metropolitan Energy Center</i>	<i>Sierra Club – Ozark Chapter</i>
<i>Missouri Botanical Garden/Gateway Center</i>	<i>Springfield City Utilities</i>
<i>for Resource Efficiency</i>	<i>Sustainable St. Louis</i>
<i>Missouri Dept. of Agriculture</i>	<i>University of Missouri-Columbia</i>
<i>Missouri Dept. of Conservation</i>	<i>Washington University</i>
<i>Missouri Dept. of Economic Development</i>	<i>Wheeler Medical Laboratories</i>
<i>Missouri Dept. of Health</i>	
<i>Missouri Dept. of Insurance</i>	

The steering committee added to and refined items on the draft list, resulting in a list of 44 action options representing a broad spectrum of “no-regrets” actions and other items that state policy makers might consider in the future. They included actions related to electricity generation and distribution, renewable energy, energy use for residential and commercial buildings, energy use for transportation, actions in the forestry and agricultural sectors and several tax incentive and revenue options. Analysis of options related to energy use in residential and commercial buildings and transportation was seen as a higher priority than analysis of industrial sector options due to the great diversity of the industrial sector, the relatively low share and slow growth rate of energy-related GHG emissions from Missouri industry compared to those from other energy end-use sectors, and the likelihood that many industries would choose to pursue GHG reduction policies at a federal or industry-wide level that transcended state boundaries. The

action options list was used as a focal point for stakeholder input at a meeting attended by about 60 stakeholders in August 1996. About 200 individuals representing a wide range of businesses and business associations, citizens' groups, university campuses and state and local government were invited to the meeting. Discussion took place in four breakout groups facilitated by steering committee members. Each group included participants from business, citizens' groups, academia and state and local government. Participants were asked to focus on the actions from the list that would be most useful to analyze rather than those they favored or opposed. They were invited to add options to the list. Stakeholders decided their own criteria for usefulness, but the criteria generally mirrored those selected by the Steering Committee. One breakout group, for example, formulated two criteria: the action should have sufficient merit to be politically feasible, and there should be a need to know more about the action and its consequences.

Following the meeting, stakeholders and steering committee members received a sheet for rating options presented at the meeting. Again, they were instructed to rate the value of analyzing the option rather than whether the action should be undertaken. About 20 stakeholders and a dozen steering committee members returned rating sheets.

After receiving summaries of stakeholder discussions and the results of the rating sheets, steering committee members endorsed a list of options to be included in the analysis and initiated several working groups that were consulted during the project.

In general, the Steering Committee and stakeholders endorsed the inclusion of voluntary, no-regret measures and an emphasis on economic, environmental and other ancillary benefits of measures studied. It was also the consensus of the Steering Committee and stakeholders that it would not be useful to analyze the impact of a federal or state carbon tax in the study.

Appendix 1: Methodology for GHG Emissions Estimates and Inventory

The 1990 Inventory report, the T&P report and this report adhere to U.S. EPA guidelines for estimating CO₂ emissions from anthropogenic sources. Detailed descriptions of the methodology used are available in the three reports, particularly the 1990 Inventory report.

The U.S. EPA's guidelines have been set out in a *State Workbook* originally published in the early 1990s and revised three times since its initial publication. Most recently (1998-99), the *State Workbook* was thoroughly reviewed, revised, updated and incorporated into the Emission Inventory Improvement Program (EIIP). The EIIP is an effort to determine standard methodologies for performing air emission inventories, jointly sponsored by the State and Territorial Air Pollution Program Administrators/Association of Local Air Pollution Control Officials (STAPPA/ALAPCO) and U.S. EPA.

The EIIP guidance on estimating greenhouse gas emissions was prepared by the GHG Committee of the EIIP in an effort to improve the quality, reliability and verifiability of inventories of sources and sinks of greenhouse gases. Committee members included U.S. EPA staff and representatives from a number of states including Missouri. The EIIP guidance is accessible through the World Wide Web.

The U.S. EPA's guidelines as set forth in the EIIP guidance adhere to international standards for GHG inventories developed by the IPCC. IPCC guidelines were published in the three-volume *IPCC Guidelines for National Greenhouse Gas Inventories* in 1997.

One element of U.S. EPA/IPCC methodology that deserves special mention is the approach used to address CO₂ emissions from biogenic sources. Biogenic sources include use of biomass energy resources and decomposition of biogenic landfill waste.

- Use of biomass energy resources may take many forms. In the utility sector, an energy crop such as switchgrass may be used as the primary energy source for generation or co-fired in a coal plant. Firewood, waste wood or waste paper may be used as a heat source in the residential, commercial and industrial sectors. In the transportation sector, ethanol or biodiesel derived from corn, soy or a lignocellulosic stock may be used as the primary fuel or added to a conventional petroleum fuel.
- Biogenic landfill waste such as lawn clippings, paper and food waste ultimately derives from plants. About half the landfill gas that is emitted when biomass decomposes in a municipal landfill is CO₂.

To avoid double-counting, GHG inventories typically count only direct emissions at a single stage of the source's life cycle. For example, a comprehensive inventory of GHG emissions from all sources would attribute zero CO₂ emissions to highway ethanol use because it counts only tailpipe emissions. If other CO₂ emissions occur in the in-state production of ethanol, these would still be included in the state inventory's aggregate total for state GHG emissions, but they would be counted in the industrial sector, not the transportation sector.

In contrast to the state inventory, policy analysis may require developing a full-fuel-cycle accounting of average GHG emissions from an energy source. A full-fuel-cycle accounting for corn ethanol would attribute zero tailpipe CO₂ emissions to ethanol use. However, CO₂ emissions per gallon of ethanol would not equal zero because the full-fuel cycle accounting does include CO₂ emissions incurred at other stages. CO₂ emissions incurred at other stages would include emissions from combustion of diesel fuel in farm machinery used in the corn field, combustion of coal or natural gas at the ethanol processing plant and combustion of diesel fuel in trucks used to deliver the ethanol to service stations. A full-fuel-cycle accounting would also include other greenhouse gases such as emissions of N₂O from on-farm fertilizer use.

An example of full-fuel-cycle accounting is included in Chapter 4 on Transportation. The Transportation chapter compares full-fuel-cycle emissions of GHG emissions from a variety of transportation fuels and technologies.

Following U.S. EPA/EIIP guidance on methods for inventorying GHG emissions, this Phase 2 project attributes zero direct GHG emissions to biogenic sources of CO₂ emissions. The U.S. EPA/EIIP guidance adheres to international standards for GHG inventories developed by the Intergovernmental Panel on Climate Change (IPCC) and published in the *IPCC Guidelines for National Greenhouse Gas Inventories* (three volumes), 1997.)

The State Workbook/EIIP methodology does recognize that other greenhouse gases (nitrous oxide and methane) and criteria pollutants such as NO_x may be emitted when biomass is burned. The “no net emissions” standard applies only to CO₂.

In order to treat CO₂ emissions in this manner, it must be assumed that the biogenic material has been grown and harvested “sustainably.” This project follows U.S. EPA/EIIP guidance in assuming sustainable production of biomass in Missouri.

For example, the EIIP chapter specifying inventory methodology for landfill emissions states that “The Intergovernmental Panel on Climate Change’s (IPCC) convention also calls for counting emissions from biogenic sources when they are harvested on a non-sustainable basis. In the United States, paper, wood and food are the primary biogenic sources of waste-related CO₂ emissions; these are all harvested on a sustainable basis.”

The following excerpts from U.S. EPA and EIIP documents provide a full explanation and rationale for this approach to accounting for CO₂ emissions from biogenic sources.

(1) Source: U.S. EPA, *Greenhouse Gas Emissions from Management of Selected Materials in Municipal Solid Waste, Final Report*, 1998, EPA530-R-98-013:

(Section 1.7): The United States and all other parties to the Framework Convention on Climate Change agreed to develop inventories of GHGs for purposes of (1) developing mitigation strategies, and (2) monitoring the progress of those strategies. The IPCC developed a set of inventory methods to be used as the international standard. (IPCC, *IPCC Guidelines for National Greenhouse Gas Inventories* (three volumes), 1997.) In selecting the methodologies used in this report to evaluate emissions and sinks of GHGs, we attempted to be consistent with IPCC's guidance.

One of the elements of the IPCC guidance that deserves special mention is the approach used to address CO₂ emissions from biogenic sources. For many countries, the treatment of CO₂ releases from biogenic sources is most important when addressing releases from energy derived from biomass (e.g., burning wood), but this element is also important when evaluating waste management emissions (for example, the decomposition or combustion of grass clippings or paper). The carbon in paper and grass trimmings was originally removed from the atmosphere by photosynthesis, and under natural conditions, it would eventually cycle back to the atmosphere as CO₂ due to degradation processes. The quantity of carbon that these natural processes cycle through the earth's atmosphere, waters, soils and biota is much greater than the quantity added by anthropogenic GHG sources. But the focus of the Framework Convention on Climate Change is on anthropogenic emissions - emissions resulting from human activities and subject to human control - because it is these emissions that have the potential to alter the climate by disrupting the natural balances in carbon's biogeochemical cycle, and altering the atmosphere's heat-trapping ability.

Thus, for processes with CO₂ emissions, if (a) the emissions are from biogenic materials, and (b) the materials are grown on a sustainable basis, then those emissions are considered to simply close the loop in the natural carbon cycle – that is, they return to the atmosphere CO₂ which was originally removed by photosynthesis. In this case, the CO₂ emissions are not counted. (For purposes of this analysis, biogenic materials are paper, yard trimmings and food scraps.) On the other hand, CO₂ emissions from burning fossil fuels are counted because these emissions would not enter the cycle were it not for human activity. Likewise, CH₄ emissions from landfills are counted - even though the source of carbon is primarily biogenic, CH₄ would not be emitted were it not for the human activity of landfilling the waste, which creates anaerobic conditions conducive to CH₄ formation.

Note that this approach does not distinguish between the timing of CO₂ emissions, provided that they occur in a reasonably short time scale relative to the speed of the processes that affect global climate change. In other words, as long as the biogenic carbon would eventually be released as CO₂, it does not matter whether it is released virtually instantaneously (e.g., from combustion) or over a period of a few decades (e.g., decomposition on the forest floor).

(Estimating Direct CO₂ Emissions from MSW Combustion, p. 81): The carbon in MSW has two distinct origins. Some of the carbon in MSW is derived from sustainably harvested biomass (i.e., carbon in plant and animal matter that was converted from CO₂ in the atmosphere through photosynthesis). The remaining carbon in MSW is from non-biomass sources, e.g., plastic and synthetic rubber derived from petroleum. We did not count the biogenic CO₂ emissions from combustion of biomass, for reasons described in Section 1.7. On the other hand, we did count CO₂ emissions from combustion of non-biomass components of MSW – plastic, textiles, and rubber. Overall, only a small portion of the total CO₂ emissions from combustion is counted as GHG emissions.

- (2) Source: U.S. EPA, *U.S. Greenhouse Gas Emissions and Sinks: 1990-2000*, Draft dated 1/11/02, p. 166:

For many countries, CO₂ emissions from the combustion or degradation of biogenic materials are important because of the significant amount of energy they derive from biomass (e.g., burning fuelwood). The fate of biogenic materials is also important when evaluating waste management emissions (e.g., the decomposition of paper). The carbon contained in paper was originally stored in trees during photosynthesis. Under natural conditions, this material would eventually degrade and cycle back to the atmosphere as CO₂. The quantity of carbon that these degradation processes cycle through the Earth's atmosphere, waters, soils and biota is much greater than the quantity added by anthropogenic greenhouse gas sources. But the focus of the United Nations Framework Convention on Climate Change is on anthropogenic emissions (emissions resulting from human activities and subject to human control because it is these emissions that have the potential to alter the climate by disrupting the natural balances in carbon's biogeochemical cycle, and enhancing the atmosphere's natural greenhouse effect.

Carbon dioxide emissions from biogenic materials (e.g., paper, wood products, and yard trimmings) grown on a sustainable basis are considered to mimic the closed loop of the natural carbon cycle, that is, they return to the atmosphere CO₂ that was originally removed by photosynthesis. However, CH₄ emissions from landfilled waste occur due to the man-made anaerobic conditions conducive to CH₄ formation that exist in landfills, and are consequently included in this Inventory.

(3) Source: EIIP, Volume 8 on greenhouse gas inventory methodology:

Introductory chapter: “[For] biomass (wood and ethanol) ... The EIIP method does not estimate carbon dioxide emissions from this source because the carbon is assumed to be recycled in new biomass growth on a sustainable basis.” (1.6-5)

Chapter 1, *Methods for Estimating Greenhouse Gas Emissions From Energy Use*, lists biomass and renewables along with nuclear and hydroelectric as “non-carbon emitting electric generation technology.” (1.8-1)

Chapter 5, *Methods for Estimating Greenhouse Gas Emissions from Municipal Waste Disposal*: “Neither the CO₂ emitted directly as biogas nor the CO₂ emitted from oxidation of methane at flares is counted as an anthropogenic greenhouse gas emission. The source of the CO₂ is primarily the decomposition of organic materials derived from biomass sources (e.g., crops, forests), and in the United States these sources are grown and harvested on a sustainable basis. Sustainable harvests imply that photosynthesis (which removes CO₂ from the atmosphere) is equal to decomposition (which adds CO₂ to the atmosphere), and thus CO₂ emissions from biogas or CH₄ oxidation are not counted in GHG inventories.”

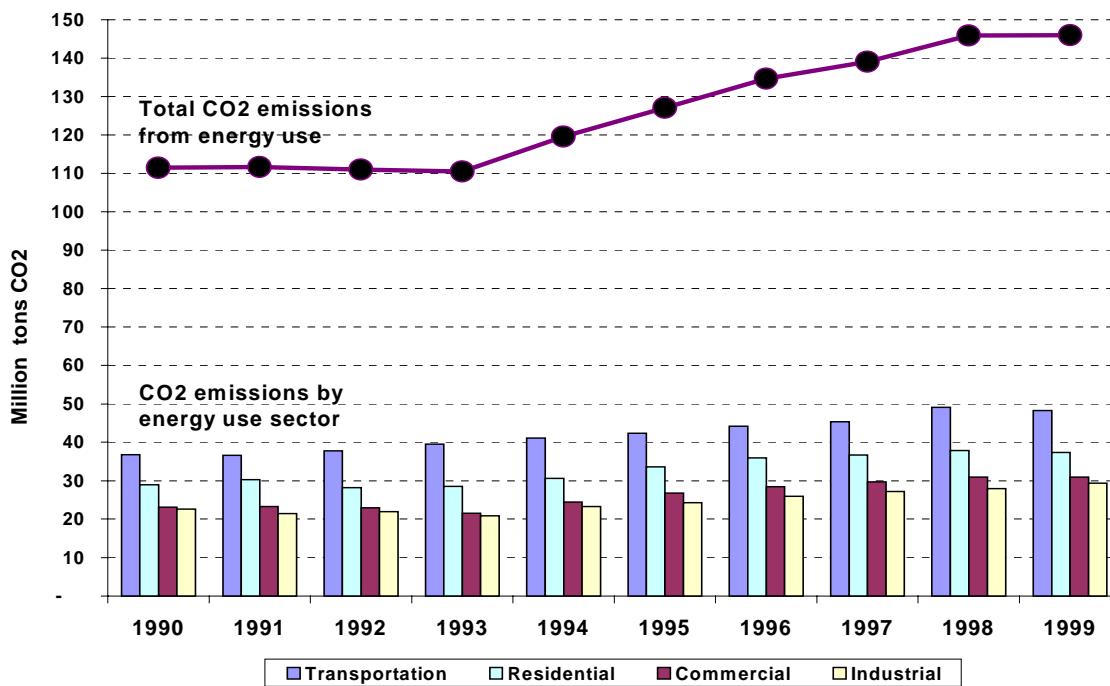
Chapter 11, *Methods for Estimating Greenhouse Gas Emissions from Crop Residues*: “Carbon dioxide emissions from crop residue burning are not considered because the carbon released as carbon dioxide during burning had been taken up from carbon dioxide in the atmosphere during the growing season.” (11.2-1)

Appendix 2: Emissions of Criteria Pollutants from Energy Use in Missouri

Unit of measure: tons. Sources: U.S. EPA Emissions Trends database; *National Air Quality and Emissions Trends Report*, 1999.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO from energy use	1,633,402	1,947,106	1,960,299	2,016,659	2,056,066	1,673,191	1,857,349	1,810,813	1,684,308	1,638,301
Transportation CO	1,465,095	1,769,961	1,779,662	1,847,613	1,902,502	1,491,255	1,678,943	1,670,005	1,565,180	1,521,281
Utility CO	7,542	7,766	7,450	6,857	8,233	9,541	8,602	9,135	9,687	9,576
Other energy CO	160,765	169,379	173,188	162,189	145,332	172,395	169,805	131,673	109,441	107,443
CO from all sources	1,816,883	2,157,742	2,175,358	2,191,895	2,249,504	1,874,361	2,093,253	1,966,670	1,841,672	1,845,747
Energy share of CO	89.9%	90.2%	90.1%	92.0%	91.4%	89.3%	88.7%	92.1%	91.5%	88.8%
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Nox from energy use	493,629	517,581	515,447	495,883	526,611	505,815	530,155	544,426	556,346	519,400
Transportation NOx	274,307	295,418	301,184	305,874	315,240	296,342	317,485	318,294	317,738	311,588
Utility NOx	194,419	195,773	189,189	164,811	186,482	183,743	187,039	201,082	214,276	182,524
Other energy NOx	24,903	26,389	25,074	25,198	24,889	25,730	25,630	25,051	24,333	25,288
Nox from all sources	510,085	534,214	532,405	511,583	543,196	523,055	548,743	561,256	573,421	536,200
Energy share of NOx	96.8%	96.9%	96.8%	96.9%	96.9%	96.7%	96.6%	97.0%	97.0%	96.9%
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
SO ₂ from energy use	864,817	816,159	740,599	522,806	634,202	427,724	432,140	383,592	371,737	327,077
Transportation SO ₂	28,677	29,689	30,504	29,459	24,398	24,858	22,731	23,412	23,966	24,568
Utility SO ₂	787,917	738,148	665,165	446,750	564,303	357,006	364,489	315,672	304,434	258,210
Other energy SO ₂	48,224	48,322	44,930	46,597	45,501	45,860	44,920	44,508	43,337	44,298
SO ₂ from all sources	969,844	920,756	845,306	627,319	739,054	533,049	537,517	490,726	480,066	436,209
Energy share of SO ₂	89.2%	88.6%	87.6%	83.3%	85.8%	80.2%	80.4%	78.2%	77.4%	75.0%
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
VOC from energy use	200,154	222,855	216,627	216,290	221,710	195,603	210,298	190,801	187,861	186,422
Transportation VOC	168,778	189,843	182,894	184,704	193,157	161,750	167,299	164,391	165,629	164,601
Utility VOC	878	889	869	796	955	1,101	1,296	1,390	1,464	1,435
Other energy VOC	30,499	32,122	32,865	30,790	27,597	32,753	41,704	25,020	20,768	20,386
VOC from all sources	428,558	454,108	450,959	446,956	459,438	438,624	409,129	381,840	372,121	368,168
Energy share of VOC	46.7%	49.1%	48.0%	48.4%	48.3%	44.6%	51.4%	50.0%	50.5%	50.6%

Estimated CO₂ Emissions from Energy Use in Missouri, 1990-1999, by Sector



Missouri Action Options for Reducing Greenhouse Gas Emissions – July 2002

Chapter 2

Options to Reduce GHG Emissions from Electric Generation in Missouri

Chapter 2: Options to Reduce GHG Emissions from Electric Generation in Missouri

Background	29
Technical Options – Centralized Generation	34
Advanced Technologies for Centralized Generation from Fossil Fuels	34
Generation from Renewable Resources	39
Technical Options – Distributed Generation	43
Advanced Technologies for Distributed Generation from Fossil Fuels	45
Generation from Renewable Resources	47
Policy Options to Reduce CO ₂ Emissions from Electric Generation in Missouri	49
Promote Utility Choice of Clean and Efficient Centralized Generation Technologies	49
Promote Distributed Generation Options	52
Promote Availability and Adoption of Cost-Effective Renewable Generation Options	56
Appendix 1 – DG Resources Sited in Missouri	60
Appendix 2 – Estimated Volume and Energy Content of Biomass and Municipal Solid Waste Resources in Missouri	63

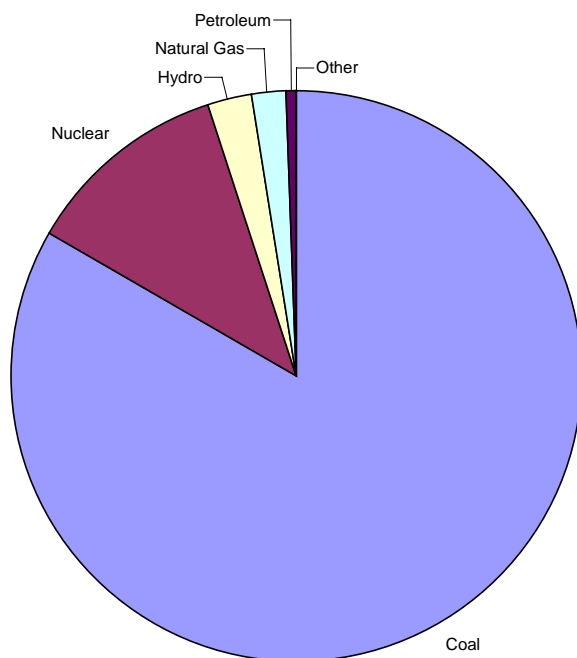
Chapter 2 - Options to Reduce GHG Emissions from Electric Generation in Missouri

Background

This chapter is focused on possible supply-side options to reduce CO₂ emissions from electric generation in Missouri. Demand-side options to reduce CO₂ emissions by increasing the efficiency with which electricity is used are discussed in the chapter on energy use in residential and commercial buildings.

Electric generation in Missouri relies primarily on centralized power plants that burn fossil fuels, particularly coal, as their energy source. In 1999, Missouri utilities generated about 73.5 billion kWh of electricity, of which about 92 percent was consumed in Missouri and the remaining 8 percent exported from the state. Based on EIA data for Missouri utility generation in 1999, about 83 percent of this total was generated from coal, about 12 percent from Missouri's sole nuclear plant, a little over 2 percent each from hydroelectric sources and natural gas and the remainder (less than 0.5 percent) from petroleum and waste. The following chart illustrates these proportions.

Chart 1: Sources of Electric Generation in Missouri, 1999



The *Trends and Projections Report* estimates that about 51.5 million tons of CO₂ were emitted from utility fossil fuel combustion to generate electricity in Missouri in 1990, and about 63.3 million tons were emitted in 1996.

Table 1 presents updated 1999 estimates for CO₂ emissions from utility electricity generation. Total emissions are estimated at about 73.5 million tons, with about 98 percent of total emissions due to generation from coal-fired plants.

Table 1: Generation, Energy Use and CO₂ Emissions in Missouri Power Plants, 1999

	Generation (MWh)	CO₂ (thousand tons)	Energy use (billion Btu)
Coal-fired generation			
Plants in Acid Rain Pgm	61,166,849	71,018	653,161
Other	82,997	96	886
Total	61,249,846	71,114	654,047
Natural Gas-fired generation			
Plants in Acid Rain Pgm	857,400	456	9,257
Other	739,902	595	10,230
Total	1,597,302	1,052	19,486
Petroleum-fired generation			
Plants in Acid Rain Pgm	58,671	69	855
Other	222,274	261	3,238
Total	280,945	329	4,093
Non-fossil-fired generation			
Nuclear	8,586,646		
Conventional hydroelectric	1,740,319		
Refuse	49,824		1
Total	73,504,882	72,495	677,627

Sources: EIA (generation and energy use); EPA (CO₂ emissions)

Methodologically, the estimates in Table 1 were derived using a different method than the estimates in previous reports on Missouri emissions. The estimates of CO₂ emissions in the *1990 Inventory* and the *Trends and Projections Report* were based on fuel consumption data, whereas the estimates presented in Table 1 are based on a method that primarily utilizes reports of emissions by utilities to EPA's Acid Rain Program. Since 1996, the largest power plants in Missouri have been required to report CO₂ emissions to EPA under the Acid Rain Program.

These plants are estimated to contribute about 99 percent of the state's total utility CO₂ emissions.

Based on the estimates in Table 1, the average input-based rate of CO₂ emissions from combustion of coal in Missouri is 217 pounds per million Btu of coal burned. By contrast, input-based emissions rates for petroleum and natural gas are 161 and 116 pounds per million Btu, respectively. The physical basis for these differences is the relative carbon intensity of the three fuels. There is further discussion of the range of carbon intensity of coal, petroleum and natural gas in the *1990 Emissions Inventory and Trends and Projections Report*.

As a cautionary note, the business-as-usual result of constructing fossil-fired plants incorporating new, less polluting technology would be to slow down the growth of aggregate CO₂ emissions, not reduce them. As discussed in the section on “incrementalism” (page 10), moving to new, less polluting technologies for new generating capacity is not likely to reduce emissions from existing plants since the existing coal fleet will most likely remain in operation, with new generating technologies coming online mainly to serve new loads. Absent some national policy decision that would result in a reduction of coal-fired generation, the most likely trend will be an increase in emissions even if no more coal-fired plants are built in the state.

Based on the data in Table 1, the average output-based CO₂ rate for overall electricity generation in Missouri is estimated to be 2 pounds of CO₂ per kilowatthour. Coincidentally, EPA recommends using a rate of 2 pounds of CO₂ emissions per kilowatthour when estimating the emissions impact of increases or decreases of electricity generation or use in a region, including Missouri. Therefore, this rate is used in this study when estimating the effect of displacing current generation resources with renewable resources or avoiding current generation by efficiency improvements.

The environmental impact of electricity generation extends beyond CO₂ emissions. The siting and operation of power plants that burn fossil fuels places environmental pressures on Missouri's water, land and air resources.

For example, power plants put heavy demands on Missouri's water supply. Generation and cooling can affect ecosystems through thermal shock, chemical discharge and increases in water solids, or turbidity. Power plants are a significant source of emissions that lead to accumulation of nitrates in drinking water and must be carefully monitored to prevent chemical contamination of groundwater, particularly in Missouri's karst geologic regions.

Natural habitats are disrupted by air- and waterborne pollution from power plants and by power plant siting and construction. Coal-fired plants, for example, produce great quantities of fly and bottom ash, most of which is disposed of in ash ponds, which potentially can leach into ground water. Coal plants must be properly decommissioned if toxic substances such as asbestos or oil residues are present or if remaining fly ash ponds are unstable.

Finally, power plant air emissions contribute to problems such as urban and rural ozone pollution (smog), respiratory and other health problems caused by fine particulates, acid rain, visibility impairment and mercury contamination in fish. Power plants emit the majority of Missouri's

sulfur dioxide (SO₂), nitrogen oxides (NO_x) and particulates. Power plants also account for a substantial share of mercury emissions.

Table 2 summarizes 1999 data from EPA's Acid Rain Program on CO₂, NO_x and SO₂ emissions from the major power plants in Missouri. Of the 21 plants reporting to the Acid Rain Program, 18 relied primarily on coal as a heat source. These 18 plants are ranked in Table 2 based on total reported CO₂ emissions during 1999. Several of these plants also generated smaller amounts of power from boilers dedicated to natural gas and/or fuel oil.

The final three power plants in the table are new plants that were brought on line by Associated Electric Cooperatives (AEC) during 1999. Like most new plants in the United States, all three generate from natural gas.

Table 2: CO₂, NO_x and SO₂ Emissions Reported by Missouri Power Plants Participating in EPA's Acid Rain Program, 1999

Plant / Utility	Generation from coal (MWh)	Generation from NG (MWh)	CO ₂ (tons)	Output-based CO ₂ rate (lb/kWh)	NO _x (tons)	SO ₂ (tons)
1 Labadie / Ameren	13,412,500		15,608,008	2.3	10,426	38,781
2 Thomas Hill / AEC	8,553,956		10,265,456	2.4	31,290	21,126
3 New Madrid / AEC	6,922,700		8,183,447	2.4	52,221	16,433
4 Rush Island / Ameren	7,548,755		8,021,847	2.1	5,692	27,196
5 Sioux / Ameren	4,508,339		5,337,653	2.4	24,170	43,773
6 Iatan / KCPL	4,541,462		4,812,489	2.1	6,430	17,397
7 Meramec / Ameren	3,030,274	58,706	3,846,320	2.5	7,812	14,700
8 Montrose / KCPL	2,649,613		3,596,551	2.7	6,514	9,669
9 Sibley / Utilicorp	3,041,817		3,365,548	2.2	18,863	26,183
10 Sikeston / Sikeston	1,751,136		2,171,460	2.5	578	7,305
11 Southwest / Spgfld	1,159,884	70,668	1,602,940	2.6	2,547	3,538
12 James River / Spgfld	1,403,633	179,970	1,585,703	2.0	4,607	5,027
13 Asbury / Empire Dist.	1,305,622		1,433,185	2.2	4,592	8,046
14 Lake Road / St. Joseph	520,245	56,093	669,334	2.3	3,099	2,088
15 Hawthorn / KCPL	286,480	184,403	383,763	1.6	567	822
16 Chamois / Central EC	307,224		292,205	1.9	1,582	8,167
17 Blue Valley / Indep.	162,066		173,967	2.1	329	5,301
18 Columbia / Columbia	61,143	681	95,749	3.1	272	723
Subtotal	61,166,849		71,445,624	2.3	181,591	256,274
St. Francis / AEC		161,456	64,579		7	
Nodaway Power Plant / AEC		86,003	21,746		33	
Essex Power Plant / AEC		59,420	11,079		24	
	61,166,849	857,400	71,543,029			

Sources: EIA (generation); EPA (CO₂ emissions). Output based emissions rates are not estimated for three AEC natural gas fired plants that started up in 1999 because the EIA data for these plants may have been reported for a different time period than the EPA data.

Given Missouri's current reliance on coal-fired generation to supply electricity demand, supply-side options to reduce CO₂ emissions from electric generation fall logically into one of two strategies, as follows:¹

- (1) Generating efficiency – increase the efficiency with which coal or other fossil fuels are used to generate electricity.
- (2) Shift in generating source – change to generation from a less carbon-intensive fuel source. Rather than coal, generate from a source such as renewable sources with zero net carbon emissions or less carbon-intensive fossil fuel sources such as natural gas.

Either of these two alternatives – improvements in generating efficiency or a shift in generating source could be applied to centralized power plants, but they could also be applied by developing new smaller, efficient on-site generation sources.

A key distinction in this chapter is that between centralized and distributed generation (DG) technologies. Distributed generation relies primarily on facilities installed on customer premises on low-voltage distribution systems. Along with facilities that are installed and are interconnected on the customer's side of the electric meter, DG may also include facilities installed by the utility on the utility side of the meter.

DG facilities may be owned, managed or dispatched by a utility, an electric customer or an energy service company. They can be used under any regulatory regime, from fully integrated utilities under traditional cost-plus regulation to full retail competition with regulated transmission and distribution utilities.

Common DG technologies include renewables such as solar photovoltaic and wind, as well as technologies that can use either a renewable or fossil source of energy such as microturbines, small gas turbines, reciprocating engines and fuel cells. As used in this chapter, the term “renewables” includes energy from wind, solar thermal energy, photovoltaic cells and panels, dedicated crops grown for energy production, organic waste biomass used for electricity production and low-head hydropower.

DG is a focus of this chapter because several technologies with the potential to reduce GHG emissions are most readily deployed as DG technologies. In addition to presenting technical options to reduce GHG emissions at centralized power plants, this chapter discusses options to reduce GHG emissions by generating power from distributed rather than centralized plants. Greater development of DG in Missouri has several potential environmental and economic benefits in addition to the reductions in GHG emissions discussed in this chapter.

¹ Theoretically, a third alternative would be capture and sequestration of carbon. There has been intensive research on technologies to sequester carbon by the International Energy Agency as well as some U.S. federal laboratories, but the quantity of CO₂ that would need to be sequestered is enormous and there is no cost-effective technology on the horizon.

Missouri currently relies on a centralized system of electric generation and distribution. While sources are lacking to estimate total DG power generated in Missouri, it is certainly less than 1 percent of the total.

In a centralized system, power is generated in centralized power plants such as those reporting to the EPA Acid Rain Program (Table 2 above). Power is distributed to end users by a system of transmission and distribution lines and is subject to line losses of several percent.

The load served by DG technologies can vary from less than a kilowatt up to 50 megawatts. In general, distributed resources tend to be smaller scale than central station power plants. In this study, DG facilities less than 100 kW are classified as small; up to 1 MW are classified as intermediate, and greater than 1 MW are classified as large.

Most of the technologies mentioned above can cover the full spectrum, including fuel cells, which are generally delivered as 250 kWh modules but can be combined to serve greater loads. Exceptions include microturbines and gas turbines. Microturbines serve small to intermediate loads, and gas turbines serve large loads.

Distributed generation facilities can be considered one element of a broader concept, “distributed resources,” which includes not only DG but also storage and load-reducing devices. Energy storage devices such as batteries and flywheels allow the user to buy power in low-cost off-peak periods and use it at peak in lieu of grid-supplied electricity. Load-reduction, more fully discussed in Chapter 3, includes classic conservation measures, passive and dispatchable load management devices and energy efficiency.

Both centralized and DG technologies have unique advantages. A system that includes both centralized and DG generating facilities is likely to be more flexible, reliable and efficient than a system that relies exclusively on one or the other.

Technical Options - Centralized Generation

Advanced Technologies for Centralized Generation from Fossil Fuels

At present, about 85 percent of the electric power generated in Missouri comes from coal-fired power plants that have operated for decades and were “grandfathered” under the Clean Air Act. “Grandfathering” refers to the practice of holding older facilities—those that were in existence when the CAA’s emission limits were adopted—to much less stringent standards than newer ones. As noted in a NARUC-sponsored study of grandfathering, the practice has had a number of perverse economic results, one of which is prolonging the life of old equipment. (Biewold et al, 1998)

With respect to CO₂ emissions, the significant characteristics of older steam turbine-based coal-fired plants is that they burn the most carbon-intensive of the major fossil fuels and that they are relatively inefficient at converting the energy in coal to electricity.

This section discusses or refers to several fossil-based technologies—natural gas combined cycle, integrated gasification combined cycle, fluidized-bed combustion and natural gas reburn, and gas-fired fuel cells—that are more efficient than conventional steam turbine coal and/or burn a

less carbon-intensive fossil fuel than coal. Replacing an older coal-fired plant with a power plant that has any of these technologies reaps immediate CO₂ reduction benefits. Replacement could occur through retrofitting a coal-fired plant, repowering (retooling the plant to burn natural gas instead of coal), outright retirement of the old plant or a more subtle shift in dispatch decisions favoring generation in the new plant over the old.

Gas-Fired Combined Cycle Generation

Gas-fired combined cycle (GFCC) systems are a proven technology with well-documented efficiency benefits. Over the past decade, GFCC systems have been reliable and much easier to finance and site than new coal-fired plants. Approximately 88 percent of planned new capacity from 1998 to 2007 will be gas-fired; only 5 percent will be coal-fired.

Any electric generation from fossil fuels results in air emissions, but generation from a GFCC plant results in substantially fewer emissions than generation from a coal-fired plant. Displacement of coal-fired generation by generation from a GFCC plant is capable of reducing the coal-fired plant's NO_x emissions by 90 percent and its SO₂ emissions by nearly 100 percent. Estimates of CO₂ emission reductions compared to conventional coal range from 50 to 66 percent. (Biewold, STAPPA/ALAPCO)

The decrease in CO₂ emissions from GFCC compared to conventional coal-fired technology is due not only to the greater energy efficiency of GFCC but also the lower carbon content of natural gas compared to coal. Indeed, due to this second factor, even conventional gas-fired technologies have lower CO₂ emissions than conventional coal-fired technologies.

Approximately 6 percent (by MW capacity) of current Missouri coal-fired boilers would be capable of burning natural gas at full load without conversion.² The conversion from coal to natural gas would reduce total state CO₂ emissions by about 2 million tons. However, because the price per Btu for natural gas is much higher than that for coal, there would be strong economic disincentives working against such a conversion.

Another technical possibility that would reduce CO₂ emissions would be to repower or retrofit existing coal-fired plants to burn natural gas instead of coal. An ideal candidate for repowering would be a plant that requires retrofit to extend its useful life and/or a plant that could be repowered with relatively minor alterations. Repowering can result in CO₂ emission reductions due to a change to less carbon-intensive fuel as well as efficiency improvements, but the technical and economic feasibility of repowering is very plant-specific.

Repowering coal-fired plants to burn natural gas is a component in the GHG reduction plans of several states such as California, Delaware, Illinois, Kentucky, New Hampshire, South Dakota and Wisconsin. However, any repowering project in Missouri would need to be initiated by the utility. At this time, Missouri utilities would probably hesitate to undertake a repowering project, given that the natural gas market has been experiencing historically high prices and low stocks. While new exploration is expected to bring increased supply to the market within the next two years, future natural gas prices and supply are very uncertain at this time.

² Personal conversation, Dave Elliott, PSC, 5/17/99

Integrated Gasification Combined Cycle

Integrated Gasification Combined Cycle (IGCC) systems replace the traditional coal combustor with a coal gasifier that is coupled with an advanced gas turbine. CO₂ emissions are reduced compared to the conventional coal-fired steam turbine due to higher energy efficiency. IGCC plant efficiencies currently can exceed 42 percent, compared to a maximum of 34 percent for conventional coal-fired steam turbines. Industry analysts anticipate that IGCC systems based on advances in gas turbine technology will experience net system efficiencies of 52 percent as early as the year 2010.

In addition to reducing CO₂ emissions, IGCC systems reduce emissions of sulfur dioxide (SO₂) nitrogen dioxide (NO_x) and particulate matter. In an IGCC system, 99 percent of the coal's sulfur is removed before combustion; NO_x is reduced by over 90 percent. Many of the waste products of an IGCC system, in contrast to coal combustion, have market potential as useful by-products.

In current IGCC systems, coal is converted into a gaseous fuel that, after cleaning, is comparable to natural gas. The process eliminates 99 percent of the coal's sulfur. An additional process further cleans the hot gas before it is forwarded to the gas turbine. Also, exhaust heat from the gas turbine is used to produce steam for a conventional steam turbine. This results in two cycles of electric power generation.

In the future, IGCC technology could be modified so that gasified coal feeds fuel cells rather than being combusted. This evolution of IGCC technology would further increase efficiency and reduce CO₂ emissions.

The primary obstacle to IGCC and other leading-edge coal technologies is that they are expensive to build. For example, the capital cost of a 260 IGCC MW demonstration project operated by Tampa Electric was \$2,300 per kWh. Similarly, the capital cost of fluidized-bed combustion (FBC) plants—another leading edge technology—ranges between \$1,200 and \$2,000 per kWh, depending on technology choice.

Co-Firing Coal with Natural Gas

Natural gas reburn is a common, inexpensive NO_x reduction technique. Gas reburning involves firing natural gas (up to 25 percent of total heat input) above the main coal combustion zone in a boiler. Most existing coal boilers can be retrofitted to incorporate natural gas reburn, although the boiler's size, type and configuration affects the specific retrofit required.

While CO₂ reduction is not the primary goal of hybrid technologies, the inclusion of natural gas in the fuel mix has the side benefit of reducing CO₂ emissions.

For example, a retrofit project at a 172 MW coal-fired power plant in Denver combined gas reburning with low-NO_x burners in order to reduce NO_x. The demonstration results showed that the technology reduced not only NO_x emissions, but CO₂ emissions as well.

Several configurations were tested in this project that reduced NO_x emissions an average of 65 percent. The CO₂ emissions were also reduced as a result of using natural gas due to its lower

carbon-to-hydrogen ratio compared to coal. At a gas heat input of 20 percent, the CO₂ emissions were reduced by 8 percent.

Fuel Cells

Fuel cells are electrochemical devices that continuously convert the chemical energy of a fuel and an oxidant to electrical energy. A typical combustion generator burns a fuel, such as natural gas, to turn a turbine that generates electricity. A fuel cell, using no moving parts, electrochemically combines fuel and air to produce electricity.

There are several types of fuel cell technologies, each named after their electrolyte. These three types are most pertinent to power plant generation:

- Phosphoric acid cells (PAFC): Most currently installed fuel cells are PAFC cells used in distributed settings, such as hospitals, that need a reliable source of power. While they will probably continue to compete in niches, their efficiency using natural gas tops out at about 38 percent, probably too low to be adopted by power plants. Their efficiency increases when fueled by hydrogen, but this is not a likely scenario for a large power plant.
- Solid oxide fuel cells (SOFC): Championed by FuelCell Power, they can achieve an average 47 percent efficiency, higher when used in a CHP application. FuelCell Power is involved in several demonstration projects and has delivered 250 kW fuel cells to one California municipal utility, but full commercialization is probably a couple of years in the future.
- Molten carbonate fuel cells (MCFC): Championed by Siemens Westinghouse, they can achieve an average 50 percent efficiency, higher when used in a CHP application. Siemens Westinghouse is a dominant manufacturer of generation equipment. MCFCs are the only fuel cell technology included in the Electricity Marketing Module used for EIA forecasts of electric generating capacity. However, MCFCs have material technical problems that must be resolved before commercial introduction.

Regardless of type, fuel cells have certain advantages. They are quiet, require relatively little maintenance, can run practically non-stop (95 percent availability factor) and are highly modular so that a power plant of any size can be configured by adding fuel cells. Their environmental benefits are as follows:

- Because they use a relatively low heat process, they produce relatively little NO_x (about 1 ppm or about .02 pounds / MWh).
- They produce essentially no SO₂ because the fuel must be sulfur-free.
- Due primarily to their efficiency, their CO₂ emissions rates are lower than the average mix of power plants and much lower than the coal-fired plants.

For example, based on a 95 percent availability factor, over the course of a year, a 10 kW fuel cell should yield about 83 thousand kWh. Assuming a fuel cell conversion factor of 50 percent, the fuel cell would emit about 66 thousand pounds of CO₂. By contrast, if the same 83 thousand kWh were generated from the current mix of power plants in Missouri, the resulting emissions would be about 2 pounds of CO₂ per kWh, or a total of 166 thousand pounds of CO₂. Therefore, installation of 10 MW of fuel cells would reduce CO₂ emissions by about 50 thousand tons

assuming that the electricity would otherwise be generated with resources whose emissions are similar to Missouri's current generation mix.

Once they are commercially available in sufficient quantity for their price to drop, SOFC and perhaps MOFC fuels will likely be the favored technology for small electric power plants and distributed generation. They produce reasonable efficiencies in 30 kW sizes, they have high efficiency even at part load conditions and they are highly modular so that a power plant of any size can be configured by simply adding units.

On the other hand, because scaling with fuel cells is by surface area rather than volume, fuel cells do not enjoy the same economies of size that are enjoyed by conventional power plants. Thus, while fuel cells are very suitable for distributed generation, they may not compete as well with other options for centralized generation.

Incrementalism vs. Immediate Replacement

This section has briefly discussed proven and leading-edge technical options for reducing CO₂ emissions from centralized, fossil fuel-based utility generation. In theory, substantial reductions of CO₂ emissions could be achieved by replacing or converting the existing stock of older coal-fired power plants to new technology. As Biewold et al comment, "With new generating technologies available with conversion efficiencies approaching 50 percent, it would make sense from a technical perspective to replace the existing capital stock of coal plants."

However, as a cautionary note, the usual result of building fossil-fired plants by incorporating new technology is simply to slow down the growth of CO₂ emissions, not reduce them. In the absence of a federal initiative such as a carbon tax, there is little economic incentive to do so.

Biewold, et al, argue that,

...based upon the economic analysis described in this report... for the most part the existing coal fleet will remain in operation, with new generating technologies coming online mainly to serve new loads. The new plants, once constructed, may operate at high capacity factors, gradually displacing existing coal generation in the dispatch. This is, however, an incremental process that will take place only very gradually over time. It is not a massive shutdown of existing coal capacity based upon a failure of the existing fleet to meet the economic challenge from new technology on a head-to-head basis...

Remarkably, this conclusion would remain true even if all coal plants had to meet new source SO₂ and NO_x standards. That is, the elimination of grandfathering of these key pollutants under the CAA would make very few coal plants uneconomic. At most, there are 97 plants, representing 6 percent of capacity that would be at risk; in fact, many of these plants would find ways to economize and remain in operation...

The vast majority of existing coal units are likely to continue in operation emitting CO₂, even in the scenario in which aggressive reductions in SO₂ and NO_x emissions are required of the existing coal fleet.

If this scenario were to unfold over time, we could expect increases in CO₂, as the existing generators remain in service primarily serving existing loads, and new generators are brought online primarily to serve new loads. The new gas combined cycle generators have CO₂ emission rates at about one half the rate per kWh of existing coal, but they do emit CO₂. As the electric power system grows, CO₂ emissions can be expected to grow as well, in the absence of specific policy to the contrary. As one example, EIA's latest reference case projection has CO₂ emissions from electric generators in the US growing by 1.5 percent annually through the year 2020. (pp 33, 43)

Generation from Renewable Resources

Renewable Resources in Missouri

Missouri's primary renewable energy resources used in centralized electricity generation are hydroelectric, wind, biomass and solar. Currently, hydroelectric generation accounts for 2 to 5 percent of all electric generation in the state, depending on factors such as annual precipitation. A study of Missouri's hydroelectric potential by the Department of Natural Resources' Division of Geology and Land Survey concluded that there are few viable sites left in the state for hydroelectric development. Therefore, this assessment focuses on wind, biomass and solar resources.

Wind: Wind resources are divided into seven wind power classes based upon the average wind speed. Wind classes three (minimum average wind speed of 14.3 miles per hour at 50 meters height) and higher are commonly accepted as the amount of wind needed to realize an economically feasible wind energy project. Although over 90 percent of our state's land area has class one or two wind resources, some areas in Missouri have been estimated to contain class three wind resources.

The best currently available estimate of Missouri's wind energy potential is contained in *Powering the Midwest*, a 1993 study produced by the Union of Concerned Scientists (UCS). The UCS study estimates Missouri's wind energy potential as 8,293 megawatts (peak) or 19,149 million kWh (annual) at less than six cents per kilowatthour. While this potential is significant compared to Missouri's annual electricity use, it is small compared to that of neighboring "wind states" such as Iowa or Kansas.

Table 3: Comparison of Wind Generation Potential in Missouri to Iowa and Kansas

	Megawatts (peak) @ <.06/kWh	Million kWh (annual)@<.06/kWh
Iowa	451,038	1,117,812
Kansas	743,706	1,866,222
Missouri	8,293	19,149

No independent wind potential study has been done for the state of Missouri. However, an independent assessment for the state of Minnesota concluded that the UCS estimate for

Minnesota if anything underestimated wind potential for that state. (personal communication, Rory Artig, MN Energy Office)

Efficiency of wind generators has increased significantly since that time. This was based on an estimated installed wind generation capacity of 109,841 megawatts. An assessment of Missouri's wind resources completed by the U.S. Department of Energy in 1987 identified the Ozark Plateau, running roughly from Joplin to Rolla, and small areas along the Missouri-Iowa border as the areas most likely to hold developable wind resources.

Biomass: Missouri has substantial biomass energy resources. A 1997 University of Missouri study estimated the total energy content of biomass, municipal solid waste and waste tires in Missouri at about 410 trillion Btu. For perspective, Missouri utilities consumed about 650 trillion Btu of coal in 1997.

The University of Missouri estimate did not include energy content of animal waste and methane from livestock operations. This was omitted due to the lack of the necessary baseline data; no inventory of Confined Animal Feeding Operations (CAFOs) was available. As discussed in the chapter on Agriculture and Forestry, animal waste and methane could potentially be used to generate electricity or for direct on-farm heating applications. Several agricultural corporations in Missouri including ConAgra, Tyson, and Premium Standard Farms are exploring this use.

The resources included in the study estimate were crop residues, wood harvesting and processing residues, municipal solid waste, waste tires and potential switchgrass production on CRP land. Waste tires, which are not a biomass resource, constituted less than 1 percent of the total estimate. On the other hand, methane emitted from landfills and livestock is a potential biomass energy resource not included in the study.

Solar: The solar resource used to generate electricity using a photovoltaic (PV) system is measured in kilowatt-hours per square meter per day, or kWh/m²/day. Missouri receives, on average, 4.9 kWh/m²/day – a solar resource that is about equal per square meter to that for Florida. What this means is that one installed kilowatt of PV electric generating capacity, with a conversion efficiency of about 10 percent (which is the present norm), would produce, on average, 1650 kWh/year. The average solar energy in Missouri does not vary appreciably across the state.

Potential for Centralized Generation From Wind, Biomass and Solar Energy

It is a generally accepted practice to attribute zero GHG emissions to wind, biomass and solar energy use. The case of biomass requires some explanation because biomass combustion undoubtedly leads to emissions of CO₂, NO_x and possibly other pollutants. It is a generally accepted practice to consider that combustion of biomass resources such as wood and energy crops results in zero net CO₂ emissions. CO₂ is emitted when biomass is burned, but it is assumed to be recycled by new plant growth.

Solar: Solar generation can use either of two technologies, thermal concentration or PV. Thermal concentration technologies use reflective materials such as mirrors to concentrate the sun's energy. This concentrated heat energy is then converted into electricity. Where sufficient solar resources are available, concentrating solar power is the least expensive solar electricity for

large-scale power generation and has the potential to make solar power available at a very competitive rate. As a result, a number of designs have been proposed, and government, industry and utilities have formed partnerships with the goal of reducing the manufacturing cost of concentrating solar power technologies. Trough collectors and power towers using sun-tracking mirrors have been demonstrated in Southwest. However, the utility-scale solar concentration technologies available at this time would require a greater solar resource than is available in Missouri.

PV technologies, which directly convert sunlight into electricity, utilize semi-conducting materials. Centralized utility-scale generation from PV arrays is currently much more expensive than other generating technologies due to the high cost of semiconducting materials. Cost-effective distributed applications for PV generation, such as building-integrated PV or meeting power needs in remote locations, are discussed later in this chapter.

This study follows the lead of previous analyses of the potential for utility-scale renewable generation in the Midwest³ by focusing on the potential for wind and biomass resources rather than utility-scale solar generation.

Wind: Large-scale wind generation has been successfully integrated into utility generation systems since the early 1980s. According to a study by Robert Putnam based on interviews with system operators and dispatchers at Pacific Gas and Electric and Southern California Edison, standard power systems and practices can readily deal with issues such as intermittence or voltage regulation. Recent announcements of large commercial wind farm ventures indicate that a combination of technological advances and marketplace changes has strengthened the suitability and attractiveness of utility-scale centralized wind farms.⁴

There have been significant advances in wind turbine components, including airfoils developed specifically for wind turbines, innovative variable- or low-speed generators, new types of rotors and advanced control systems that are responsive to complex operating environments. It has been estimated that advanced wind turbines incorporating these components could generate power at .5 cents per kilowatt-hour in 15 mile per hour winds.

Texas provides an example of a state where significant additions of centralized wind-based generation are planned. In 1999, the Texas legislature approved, and Gov. George W. Bush signed into law, a requirement that the state's utilities install or contract to buy power from 2,000 megawatts (MW) of new renewable energy generating capacity by Jan. 1, 2009.

While states such as Texas, Iowa or Kansas that have identified sites with higher-class winds seem better candidates for utility-scale wind farms than Missouri, there is reason to believe that rural Missouri has localized wind resources resulting from terrain and meteorological effects that are sufficient to support profitable utility-scale "wind farms." A key step in developing Missouri's wind resources is to better quantify the resources through re-mapping using a higher

³ For example, Union of Concerned Scientists, *Powering the Midwest*, 1995 and several state-specific follow-up studies.

⁴ "Wind farm to supply 11 western states," AP, Thursday, January 11, 2001; "As demands for energy multiply, windmill farms stage comeback," Wall Street Journal, January 26 2001.

level of precision. (See additional discussion in Chapter 5 related to renewable energy development in Missouri's agricultural sector.)

Missouri's wind resources have not been fully characterized. Full characterization of the state's wind resources, which is a prerequisite to realize the potential for distributed wind generation in the state, might also identify sites suitable for utility-scale development.

Biomass: The size of a given biomass power installation historically has been limited by low efficiencies and the amount of fuel within an economical transportation radius. The resulting low output yields a high capital cost for these systems. Recent technological developments promise to reduce or remove these constraints to the biomass power option.

Currently, there are approximately 8.5 gigawatts (GW) of grid-connected biomass electrical generating capacity in the United States, including that from landfill gas and municipal solid waste. Much of the installed capacity employs relatively inefficient direct steam technology, resulting in average efficiency for existing systems at less than 25 percent.

Efficiency improvements: Parallel to the development of advanced turbine and combined cycle technology using natural gas and gasified coal, biomass gasification technologies currently being developed could nearly double current biomass electrical generation efficiencies. Biomass generation options will continue to expand as a result of technological advances being made by government- and industry-funded gas turbine and fuel cell development programs.

Fuel requirement barrier: Technological advances are also addressing the fuel requirement barrier. Use of advanced combined-cycle technology reduces fuel requirements because of the striking increase in generating efficiency. The amount of biomass supply required to enjoy the benefits of high-efficiency generation will be further reduced by the deployment of smaller, industrial-scale gas turbines with very high efficiencies that are being developed under the U.S. DOE's Advanced Turbine System (ATS) program.

Concurrently, DOE, NREL, and ORNL are pursuing the development and demonstration of Dedicated Feedstock Supply Systems (DFSS). DFSS systems are intended to sustainably supply larger quantities of feedstock than were heretofore available.

Despite these technological advances, utilities are not likely in the next few years to build biomass-based power plants in head-to-head competition with large central station fossil-fueled plants. According to a recent NREL study, "...even the most promising electricity cost from biomass is higher than currently quoted avoided costs and new, high-efficiency natural gas combined cycle systems." (Kevin R. Craig and Margaret K. Mann, *Cost and Performance Analysis of Three Integrated Biomass Gasification Combined Cycle Power Systems*.)

Rather, as described later in this chapter, generation from biomass is likely to serve specific markets and situations as part of Missouri's distributed generation resources.

The most plausible role for biomass in centralized utility generation is probably the implementation of co-firing. Co-firing makes it feasible to use biomass in a large, centralized plant that could not rely exclusively on biomass because it would be too costly to transport biomass feedstocks from the wide area required to support the plant.

One promising biomass feedstock readily grown in Missouri is switchgrass. According to a University of Missouri study, substantial quantities of switchgrass could be cultivated on CRP land in Missouri. (See Appendix B) Switchgrass could be cultivated by Missouri farmers as a supplementary fuel for a centralized plant located in the same geographic region.

Alliant Energy is currently testing switchgrass co-firing at their 650 MW coal-fired Ottumwa Generating plant, located in Iowa close to the Missouri border. The project, begun in November 2000, will test the impact on the boiler's efficiency by replacing up to 5 percent of the coal burned in the plant with switchgrass. Bales of switchgrass, resembling bales of straw, are fed by conveyor into a machine that chops and grinds them into a dust that is blown into the furnace. Approximately 100 farmers are growing switchgrass for the Iowa plant. Jerry Schnoor, co-director of the University of Iowa's Center for Global and Regional Environmental Research, has estimated that carbon dioxide emissions could be cut by nearly 177,000 tons per year and emissions of sulfur dioxide by as much as 113 tons per year if 5 percent of the coal were replaced with switchgrass. (*Washington Post*, Promising Fuel Crops Up for an Iowa Utility, 02/10/01, pg. A02).

Of special interest is biomass reburn co-firing, due to its impact on both NO_x and CO₂ emissions. This technology, which is currently being demonstrated, uses gasified biomass instead of natural gas in the reburn process. There is an upper limit to how much biomass can be used for co-firing. However, because of the very large contribution of coal-fired plants to GHG emissions, the substitution of biomass for even a small percentage of coal burned in power plants could have a significant impact on total GHG emissions.

A number of commercial coal-fired plants already use natural gas in a reburn stage to increase efficiency and reduce NO_x emissions. A natural gas fired reburn stage reduces CO₂ emissions. Use of biomass in the reburn stage can reduce CO₂ emissions even further. DOE is sponsoring substantial research on biomass reburn. For example, research conducted during the late 1990s by General Electric demonstrated that solid as well as gasified biomass can be used in a reburn stage. Iowa State University is currently conducting DOE-sponsored research on the use of gasified biomass in the reburn stage, and a utility in North Carolina is conducting a feasibility study on the use of biomass reburn in one of their generating facilities.

Technical Options - Distributed Generation

Distributed resources are electric generation, storage or load-reducing devices that are deployed at or close to customer usage rather than in centralized locations. Distributed resources tend to be smaller in scale than central station power plants, from less than a kilowatt up to 50 megawatts—.

DG technologies, particularly fuel cells and PV, have received a great deal of attention from the energy community regarding their potential to save energy, increase the reliability of electricity supply and decrease the cost of extending the current electrical grid.

Distributed generation crosses a wide spectrum of generation technologies, including renewables such as wind, solar and biomass, and fossil-fueled sources such as diesel engines, microturbines, cogenerators and fuel cells. Demand-side management measures reduce customer load or allow customers to use their electricity in more efficient ways. These include classic conservation measures, passive and dispatchable load management devices, and energy efficiency. Energy

storage devices such as batteries and flywheels allow the user to buy power in low-cost off-peak periods and use it at peak in lieu of grid-supplied electricity.

Distributed resources may be owned, managed or dispatched by a utility, an electric customer or an energy service company. They can be used under any regulatory regime, from fully integrated utilities under traditional cost-plus regulation to full retail competition with regulated transmission and distribution utilities. Appendix 1 discusses sources on DG currently sited in Missouri.

DG is a focus of this chapter because several technologies with the potential to reduce GHG emissions are most readily deployed as DG technologies. This is only one of the multiple benefits that may accrue with the greater development of DG technologies in Missouri.

From the utility's point of view, DG can provide power directly to the customer in the 5 kW to 50 MW range, potentially deferring additional utility transmission and distribution system upgrades and improving owner quality and reliability. Ongoing research by the Electric Power Research Institute (EPRI), a utility-funded organization, indicates that DG technologies can improve local power quality subject to the influence of specific technologies and site conditions. The research also suggests that DG technologies can also eliminate or delay expensive central plant capacity additions and can be a low cost-solution for delivering power in local areas that are transmission-constrained.

Properly sited and operated distributed resources can reduce and defer investment in transmission and distribution plants. When operated in a way that reduces line and transformer loadings, distributed resources can reduce losses and the high operating temperatures that shorten plant life. Also, distributed resources may make it possible to configure a distribution system so outages affect fewer customers.

A recent resolution by the National Association of Regulatory Utility Commissioners (NARUC) board of directors states that,

...rapid deployment of DG technologies is in the public interest because:

- New technologies enhance customer choice.
- On-site generation improves customer value through control of costs and enhanced power quality and reliability.
- Distributed generation can enhance the efficiency, reliability and operational benefits of the distribution system.
- Access to distributed generation technologies can increase competition by reducing the market power of traditional power providers, particularly in transmission- and distribution-constrained regions.
- Generation close to load can reduce total electric generation costs by reducing line losses through the transmission and distribution system and associated fuel and operational costs.

- Distributed generation allows utilities to improve the asset utilization of their transmission and distribution equipment and associated financial capital and operational expenses.
- Distributed generation resources can be permitted, installed and put into use more quickly than central station generation or transmission.
- Distributed generation technologies can provide environmental benefit.

Drawing on results from an electricity capacity dispatch model to see how DG operates in the dispatch mix and what generation/emissions are displaced, Joel Bluestein has argued that “on-site generation displaces a mix of other generators... Because DG displaces a mix of new and existing generators with higher average emissions, the environmental outcome for DG is always positive.” (Bluestein, *Environmental Benefits of Distributed Generation*, p. 10)

It must be recognized that the potential air quality impacts of various DG technologies vary greatly in emissions compared to one another and to central generation. A widespread deployment of “dirty” DG technologies, such as diesel generators, could have adverse environmental effects, particularly if individual units fall below the size threshold that subjects them to regulation. Another consideration is that DG deployment typically is located at or near load centers where more people are and employs relatively short exhaust stacks that disperse emissions near ground level.

On the other hand, distributed resources such as photovoltaics and fuel cells produce significantly less air, water and noise pollution than new central station technologies. Moreover, an overwhelming environmental advantage of DG systems is that they are suitable for implementing Combined Heat and Power (CHP) solutions. In a CHP implementation, waste heat is captured to serve a useful purpose at or very near the site, raising system fuel efficiency and reducing net environmental impacts as compared to the alternative they are presumed to displace—central station generation combined with separate, on-site heat producing systems.

Advanced Technologies for Distributed Generation from Fossil Fuels

This section discusses generation technology especially suitable to distributed generation, which can generate from fossil energy resources. In addition to fuel cells, these include advanced gas-fired microturbines and CHP.

Advanced Clean Fuel Microturbines

Microturbines provide opportunities to reduce emissions by improving the efficiency with which energy is consumed through improved heat rates and combined heat and power applications. Microturbines exemplify the reduced risk in DG associated with shorter lead times and mobility. Microturbines can be delivered and installed in just a few weeks.

Microturbines are small combustion turbines with outputs of 25 kW to 1,000 kW. They are composed of a compressor, combustor, turbine, alternator, recuperator and generator. They have the potential to be located on sites with space limitations for the production of power. Waste heat recovery can be used with these systems to achieve efficiencies greater than 80 percent.

Microturbines evolved from automotive turbochargers, auxiliary power units for airplanes and small jet engines used on pilotless military aircraft. By using recuperators, existing microturbine systems are capable of efficiencies of 25 to 30 percent.

Microturbines offer a number of potential advantages compared to other technologies for small-scale power generation. These advantages include a small number of moving parts, compact size, light weight, greater efficiency, lower emissions, lower electricity costs and opportunities to utilize waste fuels.

One way turbines are classified is by the physical arrangement of the component parts: single-shaft or two-shaft, simple cycle or recuperated, inter-cooled or reheated. The machines generally rotate over 40,000 rpm, which can lead to very high stress areas. Bearing selection, whether the manufacturer uses oil or air, is dependent on usage. Generally, oil bearings last longer and are less prone to catastrophic failure, especially when power is being ramped up and down frequently. Air bearings require less maintenance and do not require an oil system and pump. Single shaft or split shaft is another design consideration. A single shaft is the more common design, as it is simpler and less expensive to build. Conversely, the split shaft is necessary for machine drive applications, which do not require an inverter to change the frequency of the AC power.

Microturbine technology efficiency is constantly being improved. However, improved efficiency can only be achieved with significant increases in operating temperature. Several materials that could be used under higher temperature conditions are ceramics and metal alloys. Development of these materials as low-cost, viable alternatives is critical for higher efficiency

Combined Heat & Power (CHP)

The term “combined heat and power” applies broadly to any process that generates electricity and useful heat from the same process. CHP achieves improved energy conversion efficiencies by using the fuel input to produce both electricity and useful heat. In centralized power plant generation, depending on the fuel and technology used, 40 to 70 percent of the heat content of fossil fuels is spent as waste heat. CHP systems permit heat output that would otherwise be lost in electricity generation to be captured and used for industrial processes such as the paper, chemical, oil and food industries, district heating applications or single-building space heating, water heating and air conditioning applications.

Compared to typical industrial boilers and electricity generating facilities, which convert 30 to 40 percent of the fuel to useful energy, generating electricity and heat or steam simultaneously can increase overall energy efficiency to as much as 80 percent, leading to reductions of NO_x and SO₂ as well as GHG emissions.

CHP installations can be large, such as the approximately 100 central heating districts in the United States, but technological advances such as the development and commercial availability of fuel cells and microturbines are making smaller scale CHP applications cost-effective in commercial and institutional building settings such as hotels, hospitals and office buildings.

On-site and near-site power generation as part of a BCHP (building combined heat and power) system brings waste heat from the turbines, gas-engines, or fuel cells close to the end-users’

thermal loads. Consequently, it can be used as the input power for heat-actuated air conditioners and dehumidifiers, to generate steam for space heating, or to provide hot water for building laundry, kitchen or cleaning services. Making use of what is normally waste heat through combined services meets the same building electrical and thermal loads with lower input of fossil fuels, yielding very high resource efficiencies.

The emissions benefits of CHP as an efficiency technology for electricity generation are substantial but depend very much on each site's energy needs and fuel choice decisions. Both the efficiency and environmental impact of CHP are enhanced if the generation technology chosen is one of the advanced DG technologies identified here, such as microturbines or fuel cells. The most appropriate fuel cell technology to use in a CHP application is one with higher heat output, such as solid oxide or molten carbonate.

Generation from Renewable Resources

The most likely role for advanced biomass generation in the next few years is as part of the DG component of the total electricity generation system, serving niche markets or taking advantage of unique opportunities. For example, an advanced technology biomass plant might be the best choice to serve a growing market for "green energy" or as part of a CHP system in locations where a specific low-cost biomass resource is readily available. There may also be specific circumstances in which biomass-based generation provides environmental advantages that lead to favorable treatment by regulatory bodies.

The capture of methane from landfills or livestock operations is a special case. These projects must be assessed on a case-by-case basis as has been done by Missouri Energy Center for several Missouri projects. Often the most practical use for the gas is localized heating needs, but electric generation may be implemented on a bottoming cycle basis to improve the efficiency of the project.

As discussed previously, Missouri has substantial solar and wind energy resources that may be suitable to the development of distributed generation.

Wind class three, defined as a minimum average wind speed of 14.3 miles per hour at 50 meters height, is commonly accepted as the amount of wind needed to realize an economically feasible wind energy project. As discussed previously in this chapter, Missouri has some class three wind resources. For example, in 2000, a wind study conducted in Nodaway County confirmed a solid class three wind resource near the town of Elmo, Missouri. Advances in wind turbine technology have made it cost-effective to generate from a single wind turbine, but additional wind characterization studies are required to identify Missouri locations suitable for generation from single turbines.

Individually-owned wind turbines are more likely to be practical in rural than urban areas of Missouri because most of the main wind turbine manufacturers say customers need at least one acre of land, and urban areas are more likely to impose height restrictions. Wind turbines are most likely to generate power efficiently at heights well above 35 feet to provide a clear wind path free of obstructions such as trees and buildings.

The up-front investment required for a typical small 3 kW wind turbine system is about \$32,000. In California, where substantial state rebate payments are available, it is estimated that a 3 kW turbine with wind speeds averaging 10 to 12 miles per hour would decrease the electricity bills by \$50 to \$200 per month and have a 5 to 10 year payback. ("Producing Winds of Change: as power prices rise, windmills are one way to decrease costs," *SF Chronicle*, Feb 27, '02.)

The comparable payback period for a small wind turbine in Missouri would depend on the wind class of the turbine location and whether state rebate payments are made available. All other factors being equal, the payback period in Missouri would be longer than in California due to Missouri's lower utility rates.

Generation from a generating source such as a residential PV system or wind turbine depends not only on its rated maximum capacity but also its capacity factor. No generating source, renewable or otherwise, generates power 24 hours a day, 7 days a week. At minimum, all generating sources require down time for maintenance. Solar and wind resources are intermittent generating sources that are not available when the sun is not shining or the wind is not blowing. Capacity factor represents the percent of theoretical generation capacity that will actually get used and is defined as "The ratio of the gross electricity generated, for the period of time considered, to the energy that could have been generated at continuous full-power operation during the same period."

Assuming that about 1 ton of CO₂ is emitted per MWh of electricity generated from the typical mix of generating resources used in Missouri, installation and use of 1 MW of a renewable (zero-emissions) generating source with a 100 percent capacity factor would reduce annual CO₂ emissions by about 8,760 tons, NO_x emissions by about 38 tons and SO₂ emissions by about 82 tons.

A typical residential PV system or wind turbine ranges from 2 to 5 kW in capacity. Therefore, a megawatt of capacity represents about 300 homes with solar or wind systems installed.

Assuming that the average capacity factor for wind and solar generation in Missouri is about 20 percent, the emissions reduction from 300 residential installations would be about 1,750 tons of CO₂, 7.5 tons of NO_x and 16.4 tons of SO₂.

The estimate of a 20 percent capacity factor for residential solar and wind systems is probably accurate for year-round use but may be low when applied to the summer cooling season. One of the most important aspects of Missouri's solar resource is that it is most available when demand for electricity is highest. That is, on the hot summer days when air conditioners are working their hardest, the potential to make electricity from the sun is also at its greatest.

Solar hot water heating is another solar technology that, while not itself a generating technology, can reduce power generated to heat water in electric water heaters. The average household with an electric water heater in Missouri's climate zone uses about 3,000 kWh (and spends about 25 percent of its home energy budget) for hot water heating. Installing a solar water heater in front of the electric water heater is estimated to reduce the household's use of electricity for water heating by 60 percent, or 1,800 kWh per year. Installation of 100 residential solar hot water heaters would reduce the need for conventional generating capacity by about 25 kW and would

reduce CO₂ emissions by about 180 tons per year. Additionally, installation of these 100 residential solar water heaters would, according to EPA estimates, reduce NO_x emissions by about 1,400 pounds and SO₂ emissions by about 2,100 pounds. Solar water heaters in Missouri have an estimated 4 to 5 year payback period, after which homeowners would accrue the savings over the life of the system, which ranges from 15 to 40 years, depending on the system and how well it is maintained.

Residential swimming pools are also prime candidates for cost-effective solar water heating. EPA has estimated that a solar application to heat an average residential pool with a 15,000 gallon capacity reduces annual CO₂ emissions by 8 tons, NO_x emissions by 45 pounds and SO₂ emissions by 70 pounds.

Policy Options to Reduce CO₂ Emissions from Electric Generation in Missouri

Missouri's Energy Future Coalition (EFC) report recommends that the state identify and promote emerging technologies in the production and use of alternative and renewable energy sources to Missouri utilities, with priority to energy sources that are indigenous to Missouri.

As suggested in the EFC report and in the preceding discussion of technical options, pursuit of this recommendation would have numerous economic and environmental benefits, one of which would be a system of electric generation less reliant on highly carbon-intensive electric generation from centralized coal-fired power plants.

Appropriate methods include providing education and information through publications, policy forums and technical meetings directed toward utilities, industry, policy makers and the general public; identifying and funding directed research and sources of technical expertise; identifying federal and other sources of funding for demonstration projects and collaborating with utilities to obtain such funds; and specifically targeted financial incentives.

In addition, state government has a significant role to play in identifying and reducing regulatory and institutional barriers to increased generation from renewable and clean distributed resources. This is particularly the case with respect to barriers to distributed generation. The existing regulatory framework for energy generation should be reviewed to identify provisions that favor centralized over distributed generation. Output-based emissions standards and pre-certification of certain types of systems could be considered. Siting difficulties, along with a lack of uniform interconnection standards across utility service territories, often lead to costly delays in project schedules. Effectively addressing technology, policy, and market barriers requires a comprehensive program strategy.

Promote Utility Choice of Clean and Efficient Centralized Generation Technologies

Background

Under any scenario, utility generation from fossil-based fuels, which presently provides about 85 percent of the energy used to generate electricity in Missouri, will continue to be a leading source of power in Missouri for many years to come. As discussed under technical options, there is wide variation in the rate of CO₂ emissions from fossil-based generating plants depending on the carbon content of the fuel used and the efficiency of the generating process.

As discussed under the action options, state agencies such as PSC and DNR have opportunities to encourage utility initiatives to voluntarily install cleaner and more efficient generating

facilities. However, under the prevailing regulatory framework in Missouri, any initiative to assess or pursue a retrofit project would probably have to come from the utility. Moreover, only the utility would have the necessary data to perform plant-specific engineering and financial analyses as part of the project appraisal.

Current circumstances in the energy and financial markets reduce the likelihood that a Missouri utility would initiate certain types of projects at this time. High prices and tight supplies in the natural gas market make it less likely that utilities would initiate projects that involve changing from coal to natural gas as a fuel source, and a tight capital market makes it less likely that utilities would initiate highly capital-intensive projects such as an IGCC plant at this time.

Because Missouri utilities are still regulated, the state could require utilities to consider new technologies in their resource planning decisions. However, the state's present role in influencing utility choice of generation technologies has been significantly limited by state-utility agreements made in the late 1990s.

In 1993, the Missouri Public Service Commission (PSC) approved a rule establishing an Integrated Resource Planning process for utilities in the state.

The rationale for IRP was widely supported at that time. For example, the Missouri Statewide Energy Study, published in 1992, pointed out that “the notion of meeting the state's energy requirements with the lowest-cost combination of supply and demand alternatives makes eminently good sense,” and that the exclusive franchise granted to electric utilities carried with it the expectation that utilities would uphold the public interest. (Energy Study VII-68).

The PSC rule, which is still on the books, gave the state a significant role in reviewing and approving supply-side as well as demand-side components of the utility's resource plan. Section 4 CSR 240-22.040 required utilities to consider—among other sources of supply—new generation technologies, cogenerators, independent power producers and efficiency improvements. It also required utilities to consider environmental costs. An example of a possible environmental cost that was analyzed in first-round utility IRP plans (1994-95) was the possible compliance costs of a carbon tax.

The Missouri Statewide Energy Study recommended an extension of Integrated Resource Planning to all regulated energy utilities in the state as well as to non-utility energy suppliers and the development of a statewide Integrated Resource Plan by the PSC. (Energy Study VII-68 to VII-69).

However, in April 1999 the PSC suspended the IRP process and substituted a twice-annual informational meeting with staff of the PSC and the Office of Public Council. (PSC, Stipulation and Agreement, 4/27/99, Case EO-99-365).

Although these informational meetings provide an opportunity for confidential data and policy review, their scope is clearly more limited than the IRP process. Moreover, the document makes no provision for public participation.

With the recent collapse of electric utility restructuring, many states have pulled back from previous plans to deregulate electric utilities.⁵ If current discussions of electric deregulation in Missouri ultimately lead to the decision to maintain a regulated utility industry, the state could increase its regulatory role as suggested in the following section. The feasibility of these options depends partly on the resolution of restructuring issues.

Whether or not electric utility regulation continues in Missouri, the state should continue efforts at collaboration with state utilities to assure the availability of clean, efficient generating resources to meet Missouri's needs for electric power. Several suggestions for collaboration are included in the following section.

Action Options

(1) Without any change in Missouri's current regulatory framework, state agencies have opportunities to encourage utility initiatives to voluntarily install cleaner and more efficient generating facilities. For example, state agencies could collaborate to:

- Make it known to Missouri's utilities that they are ready and willing to collaborate in appraising projects to retrofit coal-fired plants to the use of more efficient and less carbon-intensive projects such as those described in the technology section of this chapter, and to cooperate in searching for answers to regulatory issues that might arise.
- Discuss and resolve with EPA's regional office how such projects could proceed without forcing a plant into New Source Review status.
- Promote Missouri utility adoption of advanced biomass co-firing technologies such as reburn on the basis that it could lead to greater emissions reductions than simple mixed co-firing of biomass and coal and have additional benefits such as economic development of an indigenous energy resource. One appropriate strategy to this end would be to sponsor projects in Missouri demonstrating these technologies.

In addition, the state might explore ways to help a utility develop a tailored financial package if the utility were to propose a project advancing a cutting-edge generating technology. In general, however, the state should focus on in-kind incentives such as consulting and research and on drawing utility attention to federal programs, incentives and demonstration opportunities.

(2) Assuming that Missouri electric utilities continue to be regulated, the state could increase its regulatory role to influence utility decisions in the direction of cleaner, more efficient fossil generation. For example, the PSC could extend the framework of state collaboration and review under the 1999 Stipulation and Agreement, restore the Integrated Resource Planning process or issue specific requirements for utility investments or retrofits in advanced fossil-based generating technology.

⁵ "Other States Put Brakes on Deregulation," LA Times, March 8 2001; "Power Crisis Sours States on Deregulation," Salt Lake (NV) Tribune, February 4, 2001

(3) In concert with utility restructuring, many states are establishing a non-bypassable “Systems Benefit Charge” collected by utilities as a small percentage (for example, 0.1 percent) of electricity bills. However, the state of Wisconsin has not restructured but has created such a fund for the purposes of promoting clean, efficient distributed generation technologies, renewable energy use in the electric utility and other sectors, and end-user energy efficiency. Missouri may wish to consider this option.

Promote Distributed Generation Options

Promote Availability and Adoption by End-Users of Clean, Efficient Distributed Generation Technologies

The state has a potentially broader role in promoting distributed technologies to targeted end users. Leading-edge technologies should be selected that have demonstrable environmental and other public benefits. Technologies falling in this class include clean fuel microturbines, CHP, fuel cells and appropriately sized renewable generation projects.

The state could provide education and information to various audiences including regulatory, permitting and licensing officials on emerging distributed technologies. The technologies could be demonstrated in venues such as science museums and state green buildings. Topics could include the economic and environmental benefits and risks of new generation technologies, how they fit into their environment and the factors affecting their success. This could promote public acceptance by shattering the image that all “power plants” must be giant structures with tall, dirty stacks.

The state could identify manufacturers and institutions whose need for both power and steam make them feasible candidates for CHP systems. The state could make a long-term commitment to providing information and technical resources to these firms and inform them of innovations, special funding opportunities and clean alternatives to “dirty” DG.

In its effort to identify and reduce barriers to distributed generation, the state could ally itself with regional and national efforts such as those envisioned by the U.S. Department of Energy's Distributed Energy Resources (DER) task force. The DER task force has developed a strategic plan, which envisions that

- Over the next two decades, industrial, commercial, institutional and residential customers will be able to choose from a diverse array of ultra-high efficiency, ultra-low emission, fuel-flexible and cost-competitive distributed energy resource products and services. These will be easily interconnected into the nation's infrastructure for electricity, natural gas and renewable energy resources and operated in an optimized manner to maximize value to users and energy suppliers while protecting the environment.

The DER task force's mid-term goal for 2010 is that 20 percent of new electric capacity additions in the United States will be DG facilities. The task force's near-term goals for 2005 are to

- Develop “next generation” distributed energy technologies.

- Address the institutional and regulatory barriers that interfere with siting, permitting and interconnecting distributed energy resources coming online prior to 2005.

The National Association of State Energy Officials (NASEO) and several individual state energy offices have identified distributed energy resources as a priority target for development. NASEO, the California Energy Commission (CEC), the New York State Energy Research and Development Administration (NYSERDA) and the Association of State Energy Research and Technology Transfer Institutes (ASERTTI) have signed memoranda of understanding with U.S. DOE to conduct a variety of collaborative RD&D activities focused on DG.

The state could explore links between DG and other public policy objectives. For example, policies promoting CHP could potentially be integrated into metropolitan air quality and economic planning by strategically locating CHP in urban core areas. The Center for Clean Air Policy has identified several indirect emissions reductions that may result from such a policy. For example, if CHP facilities attract development to the site that would otherwise locate in more distant non-urban areas, the reduced emissions from redirected transportation patterns could also improve air quality.

The state could take an active role promoting and participating in integrated energy planning for the development of district energy centers. While parallel to the suspended IRP process, integrated energy planning would be an open planning process rather than a regulatory process. Recommendations for a viable planning process are available from the U.S. Combined Heat and Power Association and the International District Energy Association.

In addition to in-kind contributions such as education and technical assistance, the state could investigate carefully targeted financial incentives based on tax credits, low-interest loans or rebates. If a public benefits fund is established, the state could draw on this as a source of funding. Any incentives program providing loans or rebates would have to consider a limit on total annual funds committed and the potential costs and benefits of the program.

Identify and Eliminate Regulatory Obstacles to Fossil- and Renewable-Based DG

Output Based Emission Standards for All Generators

Where air or other emissions regulations apply to electric generation facilities, the state could continue developing the output-based emissions standard that currently exists as a placeholder in Missouri's statewide NO_x emissions plan.

Currently, the state's emissions requirements are based on input-based standards. For example, Missouri's statewide NO_x rule limits electric generating units in the western half of the state to emissions of no more than 0.35 pounds of NO_x per million Btu of heat input and in the eastern half of the state to 0.25 pounds. Analyses by EPA, the Center for Clean Air and others have established the economic benefits of output-based emissions standards in providing a reward for efficiency, and EPA has recommended eventual transition to output-based standards.

An input-based standard provides little incentive for efficiency improvements because it allows a utility to increase emissions if its energy use increases. In contrast, an output-based standard,

particularly in a trading system, bases allowable emissions levels on the quantity of electricity generated. The statewide NOx rule (10 CSR 10-6.350) reserves a section for the development of output-based standards for NOx emissions from electric generating units.

Reasonable Utility Exit Fees for CHP and Other Self-Generators

The PSC could review the issue of exit fees and negotiate a fair resolution with all stakeholders involved. There have been cases in which utility customers wishing to pursue a CHP alternative were charged prohibitively high exit fees. If creating incentives for CHP is a goal, exit fees need to be as low as possible while reflecting legitimate utility interests related to stranded costs or the value of standby transmission and distribution services.

Consistent Utility Interconnect Standards for CHP and Other Self-Generators

The state could create straightforward, reasonable, transparent standards for grid interconnection for both utility and non-utility producers. Grid interconnection of distributed CHP units such as fuel cells and microturbines allows the owner of the unit to deliver excess power to the grid when onsite generation is high and receive grid power when onsite generation is low. Utilities have legitimate reliability and safety concerns related to grid interconnection.

However, there have been many instances of utilities imposing burdensome interconnection standards that effectively discouraged CHP development. Some of these are documented in *Making Connections: Case Studies of Interconnection Barriers*, a recent publication by DOE that presents 65 case studies of technical, regulatory and business practice barriers to interconnection with adverse impacts on distributed power projects.

Standardized interconnection requirements that facilitate the siting of small DG resources, such as have been implemented in Texas and New York, are an important policy tool for encouraging DG development.

Net Metering for CHP and Other Self-Generators

The state could establish net metering. For this to occur, the Missouri legislature would need to pass legislation.

To date, 30 states have established net metering. They have established it because they want to support the development of renewable generation in their states, and net metering makes renewable generation more attractive.

Net metering simplifies an accounting issue that would otherwise be complex. In essence, net metering allows small renewable generating facility owners to run their kilowatt hour meter backwards when they are selling power to the utility and to run it forward when they are buying from the utility, resulting in a net amount for the billing period. Without net metering in place, the owner of the facility is forced to resort to a more cumbersome accounting procedure in which the administrative costs often exceed any payment received from the utility.

There is no uniform net metering standard. The states that have established net metering have defined eligibility in a variety of ways. Here is one way that eligibility might be defined in Missouri:

- Limited to renewable generation defined to include energy from wind, solar thermal energy, photovoltaic cells and panels, dedicated crops grown for energy production, organic waste biomass used for electricity production and low-head hydropower.
- Generating facility cannot be over 100 kW.
- Total statewide utility “payment” to all customers cannot exceed 10 megawatts.

Streamlined Environmental Permitting Procedures for Developers of New DG Facilities

The state could formulate streamlined environmental permitting procedures for innovative technologies meeting a performance standard such as a Clean High-Efficiency Technology (CHET) Standard.

Generation Source Disclosure & Labeling Standard

The state could require all retail electric suppliers in Missouri to disclose to their customers the sources of the electricity sold and the associated environmental impacts (CO₂, NO_x, SO₂ and nuclear waste), as well as other data oriented toward consumer protection. As a result of the information supplied, Missouri consumers would become more informed about generating resources in the state and their impact on the environment. This change in itself could have enormous impact on the way that end users in the state think about energy in general and the potential role of DG in particular.

The concept of standard information disclosure is not new. Disclosure provisions have been implemented by 25 states, and principles for an informational, user-friendly disclosure have been carefully researched and formulated by the Regulatory Assistance Project (RAP) and the National Council on Competition.

Require DG or Establish Renewable Supplementary Environmental Projects as an Alternative to Fines for Environmental Violators

State regulators like the Air Pollution Control Program (APCP) could exercise their existing authority to impose a Supplementary Environmental Project (SEP) instead of a fine on environmental violators. In effect, an SEP project is community service for corporate violators.

Under this scenario, the APCP could require a violator to establish a renewable and/or distributed energy project at a school—for example, set up a PV or fuel cell facility together with educational materials directed at the school's students. The corporate violator gains community good will, the school gains an innovative project and the community gains young citizens who understand the principles and application of cutting-edge energy technologies.

Other Regulations

The state could commit itself to monitor and identify needed changes in other federal or state regulations and regulatory practices that may create undesirable barriers to the speedy and safe installation of DG technologies. An example is the apparent mismatch of IRS depreciation schedules for generating equipment with the lifecycles of equipment used in DG.

Promote Availability and Adoption of Cost-Effective Renewable Generation Options

Promote and Provide Incentives for Selected Technologies

As recommended in the EFC report, the state should identify and promote emerging technologies in the production and use of alternative and renewable energy sources to Missouri utilities with priority to energy sources that are indigenous to Missouri.

The state's broad role in promoting renewable energy development and markets is parallel to its role in promoting distributed technologies to targeted end users. The technologies selected should be leading-edge and have demonstrable environmental and other public benefits. Technologies falling in this class include appropriately sized biomass, solar and wind generation projects. The state should also promote Green Power as a general concept and the Green Power packages offered by the state's utilities.

As with distributed generation, the state could use a variety of tools, including education, information and technical assistance directed to persons or non-regulated firms who might generate, purchase or self-generate renewable energy; explore links between biomass users and growers and rural community development issues; and include renewables in the integrated energy planing previously discussed.

The state could network among renewable energy providers to establish a regional or statewide voluntary association. The state might consider grants to such an association for purposes that serve the public interest, such as data collection and development of informational literature or technical studies.

The state could demonstrate cutting-edge biomass, PV and wind technologies on its own property, both land and facilities, including a mix of urban and remote rural end uses.

The state could monitor federal opportunities for biomass co-firing projects and work to obtain utility sponsorship of a co-firing demonstration project. The state could continue to offer assistance assessing the potential for generation from landfill or livestock methane sources on a case-by-case basis. The state, with generator and grower cooperation, could geo-map biomass and generator resources; in addition to providing perspective on biomass resources in the state, this could serve as a practical tool for individual project development.

The state could initially identify and target strategic end use niches for PV and focus promotional efforts and incentives on audiences in those niches. One purpose should be to develop a market that will attract additional suppliers into the state.

The state could monitor federal wind deployment projects for funding opportunities and could pursue federal matching funds for a detailed characterization study of the state's wind resource.

The state could complement federal tax credits and special grant or demonstration project funding with its own financial incentives. State financial incentives might be in the form of state tax credits, loans or direct assistance, either in-kind or rebates.

Funding for the activities and incentives discussed above could come from a variety of sources, including the previously described systems benefits charge on electricity sales.

Regulatory or Legislative Options

Regulation should be coordinated with federal or regional authorities where this increases its effectiveness.

Rule Requiring Utility Renewable Energy Investment

In light of the public interest in a generating system with renewable resources and a greater flexibility of supply, the PSC could establish a renewable generation investment requirement for regulated utilities.

Renewable Portfolio Standard

The state could implement a renewable portfolio standard requiring all electricity retailers to demonstrate that they have generated or purchased an amount of renewable energy generation equal to a specified percentage of their total annual kWh sales. A proper structure would advance renewable energy resources in the most efficient way possible by maximizing reliance on the market, maintain and increase the quantity of renewables in the system over a long period of time, and provide a penalty for non-compliance to ensure that retail sellers would act to meet the state's renewable energy goal.

In crafting a Renewable Portfolio Standard, Missouri could draw on an extensive literature including a recent NARUC “Practical Guide” that sets out a series of policy decisions that states might consider in formulating an RPS policy. In addition, Missouri could draw on the experience of at least ten states—Arizona, Connecticut, Maine, Massachusetts, Nevada, New Jersey, New Mexico, Pennsylvania, Texas, and Wisconsin—that have enacted renewable portfolio standards to date.

Like other state RPS programs, the Missouri program could require that increasing percentages of the state's electricity supply be provided from a menu of eligible renewable energy resources. For example, it could be required that 0.5 percent per year of supply come from renewables increasing to 6 percent in 2015.

Incorporate renewable generation into environmental regulations including State Implementation Plans

If a cap-and-trade system is established to regulate utility NO_x or other emissions, the state could set aside a certain number of allowances to be auctioned, with the proceeds used to establish renewable or energy-efficiency projects intended to reduce total NO_x emissions. This would be contingent on U.S. EPA approval of such a set-aside program.

The state could include renewable or energy-efficiency projects for emission reduction credit in a local air quality SIP, again subject to U.S. EPA approval.

Other Mandatory or Market-Based Options

Encourage or Require Each Missouri Utility to Offer a Premium “Green Energy” Package to its Customers

The state could encourage or the PSC could require Missouri's regulated utilities to acquire and offer premium shares of “green energy” to their customers.

“Green marketing” is a market-based approach to stimulating the demand and supply for renewable power by offering “green energy” to end users who wish to purchase it. It relies on the entrepreneurship of energy marketers and the preferences of end-users for “green energy” as a premium energy product. Research and experience indicate that demand exists for a “green energy” product and that many end users are willing to pay a premium for the product.

Two Missouri utilities have offered a green energy package on a voluntary basis. City Utilities of Springfield (CU), for example, began a program in Summer 2000 to sell “green” power to its residential and commercial customers. The program, called “WindCurrent,” supplies 35,000 kWh of wind-generated power each month. The source is a Western Resources, Inc. wind turbine facility located in Kansas. Customers can purchase the power in 100-kilowatt hour blocks, priced at \$5 per block to cover the cost of the wind-generated power and a portion of the program's administrative and marketing costs. The program averages a sale of about 300 blocks per month, or 30,000 kWh, to about 200 customers. CU has marketed the power with radio and print advertising, media relations, direct mail, utility bill inserts and promotional items.

CU began the program after customer research showed customer interest in a renewable power program. Subsequent customer research shows that the program has increased customer awareness of renewable power issues and has helped to reinforce the utility's standing in the community as an effective steward of environmental resources.

In fully deregulated electricity markets, a number of companies may compete to offer green energy to end users. However, in Missouri's regulated market, only electric utilities can offer to sell green energy to customers within their service territory.

Encourage or Require the Formulation of a Missouri “Green Energy” Standard

The state could participate in a voluntary effort to define a “green energy” standard. Alternatively, the state could impose a standard or create a task force of stakeholders with the mandate to formulate a standard.

The purpose of defining a green marketing standard is to assure the legitimacy and long-term viability of green marketing efforts. Green marketing programs cannot be sustained unless end users have reliable information about “green energy” and confidence in the quality of the product. Both the Federal Trade Commission and the National Association of Attorneys General recommend that the terms “green” and “environmentally friendly” not be used without specific definitions.

The most important Green Energy standards program, Green-e, is voluntary. Marketing companies voluntarily adhere to the Green-e standard because they want to market their products using the Green-e label. Participating companies must abide by the program’s Code of Conduct, make full disclosure of the sources of the electricity they are marketing, and undergo an annual verification audit of their marketing claims. Even if a different method is used to define Missouri’s green standard, Missouri might consider a similar structure.

Missouri should not simply adopt definitions from another state. For example, California’s Green-e standard does not recognize electricity from co-fired biomass as “green energy.” If Missourians want to encourage co-firing, they will need to craft a standard that is different from California’s.

Appendix 1 - DG Resources Sited in Missouri

Non-utility owners of generating facilities that generate at least 1 MW of power per year are required to report basic generation statistics to EIA. Appendix 1 lists the six Missouri universities or businesses that self-generate power at this level. Not all of the facilities listed in this table can be considered DG, and none of them use the cutting-edge technologies discussed in this chapter. There is no readily available source of inventory data for intermediate and small DG in Missouri.

Source: Compiled by Energy Information Administration from data reported on Form EIA-860B, "Annual Electric Generator Report – Non-utility."

Existing Missouri Non-Utility Electric Generating Units, by Company and Facilities, 1999

	Unit ID	Generator Nameplate Capacity (megawatts)	Net Summer Capability (megawatts)	Unit Type	Energy Source Primary ¹	Year of Commercial Operation	Unit Status ¹
Statewide total		113.7	103.2				
Anheuser Busch Inc.		26.1	23.5				
St Louis Brewery	GEN1	11.0	9.9	ST	COL	1947	OP
	GEN3	11.0	9.9	ST	COL	1948	OP
	GEN4	4.1	3.7	ST	COL	1939	OP
Archer Daniels Midland Co.		4.0	3.4				
North Kansas City	GEN1	4.0	3.4	GT	GAS	1986	OS
Hercules Inc.		15.0	13.5				
Missouri Chemical Works	GEN1	7.5	6.8	ST	COL	1943	OP
	GEN2	7.5	6.8	ST	COL	1943	OP
Southeast Missouri State Univ		7.3	6.5				
	GEN1	1.0	.9	IC	FO1	1955	CS
	GEN3	6.3	5.6	ST	COL	1972	SB
Southwestern Bell Telephone		6.0	5.6				
	E/G1	2.0	1.8	IC	DI	1992	SB
	E/G2	2.0	1.8	IC	DI	1992	SB
	E/G3	2.0	1.8	IC	DI	1992	CS
University Missouri Columbia		55.3	50.8				
	GEN1	6.3	5.6	ST	COL	1961	OP
	GEN2	12.5	11.3	ST	COL	1974	OP
	GEN3	19.8	18.4	SF	COL	1986	SB
	GEN4	14.5	13.4	ST	COL	1988	OP
	GEN5	.8	.6	GT	FO1	1971	OS

GEN6	.5	.5	IC	FO1	1994	CS
GEN7	1.0	1.0	IC	FO1	1997	CS

Codes:

Unit type: ST = steam turbine, GT = gas combustion turbine, IC = internal combustion engine

Fuel type: COL = coal, GAS = natural gas, DI & FO1 = oil

Status: OP = operating, SB = standby, CS = cold standby, OS = out of service

Appendix 2 - Estimated Volume and Energy Content of Biomass and Municipal Solid Waste Resources in Missouri

There are large volumes of unused or underutilized resources in Missouri that could be more effectively used for energy or other purposes. In 1997, the Department of Natural Resources' Energy Center funded a research project by Donald L. Van Dyne and Melvin G. Blase of the University of Missouri Agricultural Economics Department to estimate resources available in each county on an annual basis in Missouri. The attached tables are taken from that study.

Volume of resources and energy content were estimated for the following:

- Crop residues
- Energy crops that could be produced on idle CRP lands
- Wood residues from logging
- Wood residues from primary wood processing
- Municipal solid waste
- Used tires.

The University of Missouri estimate did not include energy content of animal waste and methane from livestock operations. This was omitted due to the lack of the necessary baseline data; no inventory of confined animal feeding operations (CAFOs) was available. Additional discussion of animal waste and methane is included in the chapter on Agriculture and Forestry.

The attached tables show estimates by county for all but the last two resources, municipal solid waste and used tires. These are discussed in the chapter on Solid Waste Management.

The report concluded that annual supplies of these feedstocks (excluding standing timber) contain about 409 trillion Btu. Missouri annually consumes somewhat less than 2,000 trillion Btu of energy. The authors pointed out that this was an annual estimate and that available resources might vary with changes in factors such as the level of crop production and wood harvesting. The report did not include standing timber, an important potential biomass resource in the state, because quantification of that resource is done periodically by the U.S. Forest Service.

The report also concluded that:

- Over one-half the potential Btu (56 percent) are from crop residues, but not all the residues could be removed from land and still maintain long-run sustainability. The volume that could be safely removed depends on factors that were considered beyond the scope of the study.
- Dedicated energy crops produced on CRP land could produce almost 27 percent of the total Btu available to Missouri on an annual basis. However, this resource would be more expensive than that derived from other sources. Also, Federal laws would need to be changed to allow the harvesting and use of biomass from idled CRP Lands.
- A significant volume of the residues identified in this database might not be economically collectible for various reasons including the following:

- Wood harvesting residues—these include treetops and limbs that are left when harvesting logs. They are scattered throughout the log harvesting areas.
- Crop residues—most of the wheat residue should be economically collectible, but that from other crops such as corn, soybeans and grain sorghum may not be harvestable because of adverse weather that occurs after grain harvest.

Missouri Action Options for Reducing Greenhouse Gas Emissions – July 2002

Chapter 3

Options to Reduce GHG Emissions from Residential and Commercial Buildings in Missouri

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Background	69
Technical Potential for Reductions	80
Residential Sector	81
Commercial Sector	82
Technical Potential Versus Achievable Potential	83
End Uses with Greatest Technical Potential for Reductions	84
Advanced Building Technologies	85
Policy Options	86
Energy Information and Education	88
Standards and Codes	90
Federal Appliance Standards and Energy Labels	90
Building Energy Codes	92
Voluntary Programs and Partnerships – Public Buildings	96
Energy Efficiency in State Facilities	96
Programs and Partnerships to Promote EE/RE in Other Public Buildings	99
Voluntary Programs and Partnerships – Residential Buildings	103
Low-Income Weatherization	103
Incentive Programs	109

Chapter 3 - Options to Reduce GHG Emissions from Residential and Commercial Buildings in Missouri

Background

Greenhouse gas (GHG) reductions in residential and commercial buildings must be a key component of any GHG reduction plan. Internationally, a recently released Assessment Report of the International Panel on Climate Change Working Group III assigns greater potential for GHG reductions to this sector than to any other, including transportation and industry.

As documented in the *Trends & Projections Report*, carbon dioxide (CO₂) emissions from energy use in Missouri account for about 70 percent of the state's total gross¹ GHG emissions, and the portion of total emissions from this source has been increasing. Nearly half (48 percent) of total CO₂ emissions from fossil fuel combustion come from residential and commercial buildings.

This chapter is complementary to the chapter on generation. It focuses on energy use whereas the Generation chapter focuses on energy supply. Any plan to reduce GHG emissions must include complementary and coordinated supply-side and demand-side components – reducing the emissions associated with energy production, particularly electric generation while simultaneously introducing technologies and incentives for Missourians to use energy more efficiently and with less waste.

This chapter will focus on identifying and analyzing ways to reduce CO₂ emissions from use of electricity and natural gas in Missouri's residential and commercial buildings. The justification for focusing on these two “fuels” is that electricity and natural gas use is responsible for the majority of energy use in Missouri buildings that results in CO₂ emissions.

Energy Use in Missouri Buildings

Table 1a summarizes energy use in the residential and commercial sectors in 1990, a reference year, and 1997, the most recent year for which there are comprehensive state level energy statistics.

¹ Gross GHG emissions is estimated as total emissions of CO₂, methane, nitrous oxide and perfluorocarbons prior to adjusting for sequestration due to forest growth. For further explanation, see the *Trends & Projections Report*, Chapter 1.

Table 1a: Energy Consumption in Missouri's Residential and Commercial Building Sectors

	Residential			Commercial			Total		
	1990	1997	Change	1990	1997	Change	1990	1997	Change
Electricity									
Trillion Btu	74	91	23%	66	81	23%	140	172	23%
Billion kWh	22	27		19	24		41	50	
Natural gas									
Trillion Btu	117	129	10%	60	70.5	18%	177	199	13%
Billion cubic feet	116	128		59	70		175	198	
Propane									
Trillion Btu	15	25	65%	3	4	66%	18	30	65%
Million gallons	176	291		31	52		207	343	
Other petroleum									
Trillion Btu	2	2	0%	7	8	22%	9	11	17%
Coal	2	2	0%	4	4	-3%	6	6	-2%
Wood	13	10	-27%				13	10	-27%
Total (trillion Btu)	224	259	16%	140	168	21%	363	427	17%

As the table illustrates, electricity and natural gas are the dominant energy sources used in Missouri buildings. As further discussed in the next section, the CO₂ impact of electricity use in buildings is estimated based on CO₂ emissions from electric generation in response to demand for electricity. Therefore, electricity use is more important as a source of CO₂ emissions than the simple comparison of on-site energy use in Table 1a suggests.

After natural gas, propane is the most important residential heating fuel used in Missouri, particularly in rural areas or other locations where natural gas is not available. Propane use in both the residential and commercial building sectors increased during the '90s, possibly reflecting population shifts that will become more apparent as information from the 2000 census becomes available.

Outside of the St. Louis area, very little fuel oil is used for residential heating in Missouri. Commercial petroleum consumption is less than half that of the residential sector and is scattered across several commodities.

Policies intended to reduce the environmental impact and other costs of energy demand in Missouri's residential and commercial sectors by promoting greater use of energy-efficient technologies must deal with a moving target. This chapter, following generally accepted practice, compares the impact of energy efficiency and renewable energy policies on energy use and emissions levels to "business-as-usual" projections as well as to past consumption and emissions levels.

In the residential sector, the average United States home in 2020 is expected to be 5 percent larger than the average home in 1999, with correspondingly greater needs for heating, cooling and lighting. It also is expected to rely more heavily on electricity-based technologies, as the "all other" category of electricity end use (including computers, dishwashers, clothes washers and

dryers and a multitude of other appliances) continues to grow in importance. Similarly, in the commercial sector, high energy use growth rates are expected for computers and other office equipment that has not yet saturated the commercial market. [Energy Information Administration (EIA) Annual Energy Outlook (AEO) 2001, pp. 63-65]

Table 1b presents projections of Missouri residential and commercial electricity and natural gas consumption through the year 2020. The Missouri projections are based on national projections for increases in national residential and commercial energy use from EIA's Annual Energy Outlook 2001.

Table 1b: Projected Electricity and Natural Gas Use in Missouri Buildings Through 2020
Assuming "Business-as-Usual"

	1990	1998	1999	2010	2020	Growth rate (1990-2020)
<i>Electricity use (million kilowatthours)</i>						
Residential						
Space Heating	2,180	2,713	2,698	3,306	3,641	1.7%
Space Cooling	3,312	4,122	3,685	4,451	5,471	1.7%
Water Heating	2,333	2,904	2,799	3,056	3,075	0.9%
Refrigeration	2,601	3,237	3,032	2,433	2,310	-0.4%
Cooking	604	751	726	848	939	1.5%
Clothes Dryers	1,263	1,572	1,535	1,838	2,059	1.6%
Freezers	727	905	837	632	622	-0.5%
Lighting	1,958	2,437	2,411	3,277	3,684	2.1%
Clothes Washers	174	217	209	244	272	1.5%
Dishwashers	126	157	151	171	195	1.5%
Color Televisions	680	846	859	1,346	1,695	3.1%
Personal Computers	65	391	455	666	812	8.8%
Furnace Fans	434	540	529	690	821	2.1%
Other Uses	5,197	7,471	7,840	12,302	15,628	3.7%
Total Residential	21,652	28,265	27,766	35,260	41,226	2.2%
Commercial						
Space Heating	783	921	956	1,109	1,085	1.1%
Space Cooling	2,651	3,119	2,888	3,100	3,134	0.6%
Water Heating	830	977	982	1,084	1,066	0.8%
Ventilation	906	1,168	1,179	1,392	1,425	1.5%
Cooking	166	214	215	210	192	0.5%
Lighting	6,897	8,116	8,214	9,671	10,006	1.2%
Refrigeration	953	1,228	1,241	1,451	1,525	1.6%
Office Equipment (PC)	251	638	709	1,616	1,997	7.2%
Office Equip (non-PC)	870	1,904	2,006	3,458	4,685	5.8%
Other Uses	5,027	6,634	6,699	10,078	12,958	3.2%
Total Commercial	19,335	24,920	25,088	33,169	38,074	2.3%
<i>Natural gas use (billion cubic feet)</i>						
Residential						
Space Heating	75,829	72,446	74,379	89,026	99,583	0.9%
Space Cooling	3	4	8	47	82	12.1%
Water Heating	31,064	29,679	29,157	32,618	35,164	0.4%

Cooking	4,628	4,422	4,336	5,207	5,877	0.8%
Clothes Dryers	1,609	1,537	1,536	2,074	2,522	1.5%
Other Uses	2,817	2,691	2,626	2,616	2,500	-0.4%
Total Residential	115,950	110,779	112,042	131,590	145,727	0.7%

Commercial

Space Heating	25,719	26,742	28,336	34,751	36,288	1.1%
Space Cooling	178	292	304	481	553	3.8%
Water Heating	11,995	12,522	12,853	15,362	16,821	1.1%
Cooking	3,830	3,998	4,119	4,975	5,397	1.1%
Other Uses	17,665	18,441	17,487	22,142	23,518	0.9%
Total Commercial	59,387	61,995	63,100	77,711.6	82,578	1.1%

CO₂ Emissions Attributable to Energy Use in Missouri End Use Sectors

The following table duplicated from the *Trends and Projections Report*, summarizes trends in Missouri CO₂ emissions from fossil fuel combustion between 1990-1996. In this table, emissions from electric generation are apportioned to electricity end use sectors based on their consumption of electricity.

Units: 1,000 Short Tons Carbon Dioxide (CO₂)

	1990	1991	1992	1993	1994	1995	1996
Transportation	36,782	36,636	37,813	39,542	41,118	42,354	44,210
Commercial	23,104	23,262	22,937	21,551	24,483	27,681	29,847
Industrial	22,649	21,447	22,010	20,869	23,357	23,747	24,338
Residential	28,937	30,292	28,218	28,557	30,649	33,374	35,581
Total end-use sectors	111,472	111,638	110,977	110,519	119,608	127,156	133,976

CO₂ Emissions From Natural Gas Consumption in Missouri Buildings

Data on annual Missouri consumption of natural gas and electricity is available through the year 1999. In 1999, Missouri's residential and commercial sectors combined consumed approximately 175 billion cubic feet of natural gas, about two-thirds of the total consumed in the state. This total was slightly higher than consumption in 1998 and lower than consumption in 1996 and 1997. Consumption of natural gas in these sectors varies annually and is affected by the severity of weather during the winter heating season.

Natural gas emissions from residential and commercial buildings can be projected based on EIA's projections for the United States in the AEO 2001. The annual average rate of growth (AARG) projected for CO₂ emissions between 1999 and 2020 from these sectors is about 1.3 percent.

Table 2: Historic and Projected CO₂ Emissions from Natural Gas Use in Missouri Buildings
(in thousand short tons)

Residential					
	1990	1998	1999	2010	2020
Space Heating	4,461	4,216	4,329	5,181	5,796
Space Cooling	0	0	0	3	5
Water Heating	1,828	1,727	1,697	1,898	2,047
Cooking	272	257	252	303	342
Clothes Dryers	95	89	89	121	147
Other Uses	166	157	153	152	145
Total residential	6,822	6,447	6,521	7,659	8,481
Commercial					
Space Heating	1,513	1,556	1,649	2,023	2,112
Space Cooling	10	17	18	28	32
Water Heating	706	729	748	894	979
Cooking	225	233	240	290	314
Other Uses	1,039	1,073	1,018	1,289	1,369
Total commercial	3,494	3,608	3,672	4,523	4,806
Total building	10,316	10,055	10,193	12,181	13,287

Based on these numbers, the projected business-as-usual AARG for Missouri residential CO₂ emissions from natural gas would be 0.6 percent for 1990 through 2010 and 0.7 percent for 1990 through 2020. Thus, this is not projected to be a high-growth sector.

Historic data for natural gas use in Missouri buildings suggests that the projections in Table 3, which are based on national projections, may represent the upper limit for future increases in CO₂ emissions from natural gas use in Missouri buildings. Between 1990 and 1997, natural gas use in buildings increased more rapidly in the United States as a whole (17 percent) than in Missouri (13 percent). Natural gas use in buildings decreased between 1997 and 1999 nationally and in Missouri, but the decline was steeper in Missouri. Total natural gas consumption in Missouri residential and commercial buildings was about the same in 1999 as in 1990; nationally, the 1999 consumption was about 11 percent higher than in 1990.

CO₂ Emissions From Electricity Consumption in Missouri Buildings

In general, the greatest impact of residential and commercial buildings on state GHG emissions is their indirect demand for fossil fuels, particularly coal, used to generate electricity used in Missouri's buildings. This is due to two factors: the high carbon intensity of electricity use and the rapid growth of electricity use in Missouri's building sectors.

- Carbon intensity: The gap between the on-site energy content of electricity used in buildings and the content of the fuel required to generate it reflects inefficiencies inherent in centralized electric generation and distribution. About 10 thousand Btu of coal has to be combusted to deliver one kilowatt hour of electricity to the end user. Thus, the heat content of the electricity consumed on-site within the building sectors in 1999 equaled about 180

trillion Btu. The estimated heat content of coal and other fuel used to generate that electricity at power plants was nearly three times that total, more than 500 trillion Btu. About two pounds of CO₂ emissions are attributable to consumption of that kilowatthour of electricity – about double the CO₂ that would be emitted using a comparable amount of energy in an efficient natural gas application.

- **Rapid Growth:** As documented in the *Trends and Projections Report*, electricity use in the residential and commercial building sectors has been the fastest-growing component of Missouri GHG emissions during the past decade, and about 80 percent of commercial CO₂ emissions and more than 70 percent of residential CO₂ emissions are from electricity use.

CO₂ emissions from electricity consumption in Missouri buildings may be projected using the same methods as those used for Table 2. The resulting projections are as follows:

Table 3: Historic and Projected CO₂ Emissions from Electricity Use in Missouri Buildings (in thousand short tons)

<u>Residential</u>	1990	1998	1999	2010	2020
Space Heating	2,083	2,670	2,567	3,146	3,465
Space Cooling	3,165	4,057	3,506	4,235	5,205
Water Heating	2,230	2,858	2,663	2,907	2,926
Refrigeration	2,485	3,185	2,885	2,315	2,197
Cooking	577	739	691	806	894
Clothes Dryers	1,207	1,547	1,460	1,749	1,959
Freezers	695	891	796	601	592
Lighting	1,871	2,398	2,294	3,118	3,505
Clothes Washers	167	213	199	233	259
Dishwashers	120	154	143	163	186
Color Televisions	650	833	818	1,281	1,613
Personal Computers	62	385	433	634	773
Furnace Fans	415	532	504	657	781
Other uses	4,967	7,352	7,459	11,704	14,869
Total residential	20,694	27,815	26,418	33,548	39,224
<u>Commercial</u>					
Space Heating	759	907	909	1,055	1,033
Space Cooling	2,570	3,069	2,748	2,949	2,982
Water Heating	805	961	935	1,031	1,014
Ventilation	879	1,149	1,122	1,325	1,356
Cooking	161	211	204	200	183
Lighting	6,688	7,987	7,815	9,202	9,520
Refrigeration	924	1,209	1,181	1,380	1,451
Office Equipment (PC)	244	628	674	1,537	1,900
Office Equipment (non-PC)	844	1,874	1,909	3,290	4,457
Other Uses	4,875	6,528	6,374	9,588	12,329
Total Commercial	18,749	24,523	23,870	31,558	36,225
Total building	39,443	52,338	50,288	65,106	75,449

The estimates in Tables 2 and 3 are based on Annual Energy Outlook 2001 projections for the North West Central Region. The assumptions underlying AEO projections are described in great detail in Appendix G of the AEO 2001 report, available at www.eia.doe.gov/oiaf/aeo/appg.html.

For the residential sector, these include assumptions about baseline residential energy consumption patterns and shell and equipment efficiency; the impact of established federal equipment standards and business-as-usual technology improvements; stock turnover rates; and other trends such as increasing square footage in new residential construction. The projected effects of equipment turnover and the choice of various levels of equipment energy efficiency are based on tradeoffs between normally higher initial purchase cost for more efficient equipment versus lower annual energy costs.

An increase in CO₂ emissions at levels indicated in these business-as-usual projections would present a major challenge to achieving goals such as the Kyoto Protocol goal of reducing future emissions below 1990 levels. As Table 4 indicates, very large percentage increases are projected for CO₂ emissions in the residential and commercial sectors between 1990 and 2020. The corresponding average annual rates of growth for CO₂ emissions from electricity use in buildings are a 2.5 percent business-as-usual AARG for the period between 1990 and 2010 and an AARG of 2.2 percent through 2020.

Table 4: Projected Increases in CO₂ Emissions Under “Business-as-Usual” Through 2020

	Percentage increase, 1990-2010	Percentage increase, 1990-2020
Residential		
Electricity	62%	90%
Total	50%	73%
Commercial		
Electricity	68%	93%
Total	62%	84%

Historic data for electricity use in Missouri buildings suggests that the projections in Table 4, which are based on national projections, could be exceeded in Missouri. The AARG projected for CO₂ emissions between 1999 and 2020 from these sectors is about 2.0 percent. Between 1990 and 1999, electricity use in Missouri residential and commercial buildings increased at an AARG of 2.7 percent. The *Trends and Projections Report* documented a trend of steadily increasing utility CO₂ emissions throughout the '90s.

The most recent available data on utility CO₂ emissions trends, from 1998 and 1999, does indicate a reversal of this trend. The owners of power plants covered by U.S. EPA's Acid Rain program, a group that includes all the major fossil-fired power plants in Missouri, reported total CO₂ emissions of 71.5 million tons in 1999, a 2 percent decrease from 72.7 million tons in 1998.

In part, this reversal of trend reflects a decrease in residential and commercial electricity consumption between 1998 and 1999. In 1999, Missouri's residential and commercial sectors combined consumed approximately 52.9 billion kWh of electricity, 77 percent of the total consumed in the state. As indicated in Table 5, consumption by these sectors in 1999 decreased slightly from the previous year, reversing a long-term trend. The likely explanation for the decrease is that consumption was affected by less severe weather during the 1999 summer cooling season.

Table 5: Missouri Electricity Use, 1998 and 1999

	1998	1999
<i>In-state sales (million kWh)</i>		
<i>Residential</i>	28,265	27,766
<i>Commercial</i>	24,920	25,088
<i>Industrial</i>	15,801	16,122
<i>Total</i>	68,986	68,976

However, the major reason for the interruption of trend was a one-time event. In 1999, KCPL's Hawthorn coal-fired plant was lost due to a maintenance accident. When the Hawthorn plant was in operation, its annual CO₂ emissions totaled about 2.6 million tons. The plant was rendered inoperable by the accident and will not be reopened. Some of the generating capacity of this plant is being replaced with natural-gas-fired generating facilities that have lower CO₂ emissions than the original coal-fired facility.

Emissions of Criteria Pollutants Attributable to Energy Use in Missouri Buildings

There are two data sources for estimating building sector emissions of criteria pollutants. First, for criteria pollutants from all energy use in buildings, U.S. EPA's annual emissions inventories provide a basis for estimates. The inventories provide a means to compare Missouri building sector contributions to total statewide emissions of criteria pollutants through 1997.

Second, for criteria pollutants from electricity use only for the more recent years 1998 and 1999, it is possible to draw on reports by operators of plants covered by the Acid Rain program because they are required to monitor and report emissions of oxides of nitrogen (NO_x) and sulfur dioxide (SO₂) as well as CO₂.

The data in Table 6 are from U.S. EPA's emissions inventory for 1997. As the table indicates, commercial and residential buildings, either directly or through consumption of electricity, contribute at least 67 percent of Missouri's SO₂, 31 percent of Missouri's nitrogen oxides (NO_x) and half of Missouri's particulate emissions (PM₁₀). For volatile organic compounds (VOC) and carbon monoxide (CO) emissions, on the other hand, the impact of buildings is secondary to that of transportation and industry. The estimates in Table 6 probably understate the impact of buildings because they do not take into account emissions from unregulated sources such as natural gas and propane use in residences.

Table 6: Estimated Emissions of Criteria Pollutants from Missouri Fossil Fuel Use in Residential Buildings, Commercial Buildings and Other Sectors

	NOx	SO ₂	VOC	CO	PM10
Residential	82,991	131,491	24,594	130,379	16,616
Electricity	81,455	127,847	576	3,817	1,268
Other	1,535	3,643	24,018	126,562	15,348
Commercial	76,793	122,577	795	4,570	1,453
Electricity	72,870	114,373	515	3,415	1,134
Other	3,923	8,204	279	1,155	319
Residential & Commercial	159,784	254,067	25,389	134,948	18,069
Total from all energy sources	515,834	386,340	180,851	1,706,565	34,682
Comm/Res % of Total	31%	66%	14%	8%	52%
2020 reduction @ 7.5% saved	14,381	22,866			1,626

Table 7 estimates NOx and SO₂ emissions from building electricity use in 1998 and 1999. In order to estimate the portion of total emissions attributable to electricity use in buildings, total emissions were discounted to account for exports and then allocated to end use sectors based on those sectors' total consumption of electricity. The statewide emissions totals had to be discounted because total electric generation in Missouri exceeds in-state consumption. A portion of the state's total electricity production – 6.6 percent in 1998 and 8.3 percent in 1999 – is exported rather than consumed in the state.

Table 7 summarizes the resulting estimates of emissions attributable to the use of electricity in the state's residential and commercial building sectors. As noted above, buildings accounted for about 77 percent of in-state electricity use and about 70 percent of total utility emissions in 1998. The remaining 30 percent of utility emissions is attributable to electricity use by Missouri industry (21 percent) and exports (9 percent).

Table 7: CO₂, NOx and SO₂ Emissions Attributed to Electricity Use in Missouri Buildings

<i>Total due to in-state demand</i>		
SO ₂ (tons)	272,757	235,082
CO ₂ (tons)	67,886,783	65,626,938
NOx (tons)	196,915	166,633
<i>Due to residential demand</i>		
SO ₂ (tons)	111,754	94,631
CO ₂ (tons)	27,814,628	26,417,849
NOx (tons)	80,680	67,077
<i>Due to commercial demand</i>		
SO ₂ (tons)	98,529	85,504
CO ₂ (tons)	24,522,927	23,869,877
NOx (tons)	71,132	60,608

Relationship of Energy Efficiency and Renewable Energy Measures to Criteria Pollutant Reduction and Electric Capacity Issues

The concept of a multi-pollutant emissions control strategy has gained support from pollution control officials and policy makers at all levels of government. As noted in the above discussion, significant levels of three pollutants – CO₂, NO_x and SO₂ – can be attributed to electricity consumption in buildings. This provides a framework for the emphasis of the policy section of this chapter on energy efficiency and renewable energy (EE/RE) strategies to reduce CO₂ emissions from buildings. Unlike other pollution control strategies, EE/RE strategies tend to reduce levels of all pollutants. This point is elaborated in the State and Territorial Air Pollution Program Administrators/Association of Local Air Pollution Control Officials (STAPPA/ALAPCO) report.

The EIA has projected that in the United States, overall energy use in buildings will increase about 20 percent between 1997 and 2020. If emissions of criteria pollutants were to increase in proportion to energy use, this would imply a business-as-usual (BAU) projection of about 190 thousand tons of NO_x and 305 thousand tons of SO₂ attributable to Missouri's building sector in 2020.

However, unlike CO₂ emissions, which bear a direct relation to the carbon in combusted fuels, pollutants such as SO₂ and NO_x bear a somewhat loose relationship to the quantity of fuel use. The level of NO_x emissions, for example, is also related to factors such as the nature of the combustion process and the presence or absence of pollutant-specific control devices such as scrubbers. It is likely that actual emissions of NO_x will be lower than the business-as-usual estimate presented above due to implementation of air pollution control policies such as adherence to U.S. EPA's NO_x State Implementation Plan (SIP) call and a recent state rule requiring Missouri power plants to reduce their NO_x emissions. Nevertheless, given a specific mix of generation sources, a reduction in end use of electricity through EE/RE measures has a measurable and predictable impact on total NO_x emissions. Guidelines for estimating and verifying such reductions can be found in U.S. EPA's guidance for EE/RE programs related to the NO_x SIP call and in U.S. EPA's recently established policy for inclusion of voluntary reductions of stationary source emissions in state SIPs.

In addition to its impact on emissions, strong and growing electricity demand puts pressure on the peak generating requirements for assuring reliability of electricity supply in the state. The Missouri Public Service Commission (PSC) has estimated that Missouri investor-owned utility (IOU) capacity must increase by a 2.1 percent AARG over the next three years to meet capacity requirements, as follows:

	2001	2002	2003	2004	AARG
IOU capacity requirements	15,963	16,470	16,704	17,003	2.13%

As discussed in the chapter on electric generation, capacity requirements are based on peak demand, and therefore, there are demand-side as well as supply-side options to assure reliability of electric power in the state.

Electricity End Uses in Missouri's Residential Sector

Missouri's residential and commercial buildings include a diverse array of energy end uses within varying sizes and types of buildings. Using data purchased from a proprietary source, F.W. Dodge, the House Concurrent Resolution 16 (HCR16) study, conducted by the Environmental Improvement and Energy Resources Authority (EIERA) in 1993, did develop three residential and six commercial building models that were estimated to collectively represent about four-fifths of the building activity in Missouri. The HCR16 study estimated that in 1995, the standing stock of residential housing was 2.4 billion square feet and the standing stock of commercial buildings was 1.25 billion square feet. The study estimated that the residential stock would increase to about 2.6 billion square feet by the year 2000 and the commercial stock to about 1.38 million by that year. It is likely that these HCR16 projections significantly underestimated the actual square footage of new construction that was added to these sectors since the state enjoyed unexpected economic and population growth between 1995 and 2000.

Electricity is a versatile form of energy suitable for many end uses, both traditional uses, such as lighting and heating, and exclusive uses such as audio/video equipment, computers and other new or not-yet-commercialized electronic appliances. In the United States, these latter "miscellaneous" uses are the largest and fastest-growing category of residential electricity use. In the commercial sector, on the other hand, lighting accounts for about twice as much electricity use as "office equipment" and other miscellaneous end use categories.

Table 8, drawn from EIA's AEO, indicates estimated end-use shares of residential electricity between 1990 and 2020. The data in this table is based on EIA's triennial consumption surveys and other sources. It indicates that nationally, about 24 percent of residential electricity use is for space heating and cooling, nearly 15 percent for food preservation (refrigeration and freezing), about 10 percent for water heating and 9 percent for lighting. The "miscellaneous" category that accounts for about 37 percent in EIA's triennial surveys is broken into several categories here, including personal computers and "other uses." "Other uses" is the fastest-growing category, including a wide range of appliances and equipment such as home electronics and audio-visual equipment.

Table 8: Estimated End Use Share of Electricity Consumption in Residential Buildings, 1990-2020

	1990	1998	1999	2010	2020
Space Cooling	15.3%	14.6%	13.3%	12.6%	13.3%
Refrigeration	12.0%	11.5%	10.9%	6.9%	5.6%
Water Heating	10.8%	10.3%	10.1%	8.7%	7.5%
Space Heating	10.1%	9.6%	9.7%	9.4%	8.8%
Lighting	9.0%	8.6%	8.7%	9.3%	8.9%
Clothes Dryers	5.8%	5.6%	5.5%	5.2%	5.0%
Color Televisions	3.1%	3.0%	3.1%	3.8%	4.1%
Freezers	3.4%	3.2%	3.0%	1.8%	1.5%

Cooking	2.8%	2.7%	2.6%	2.4%	2.3%
Furnace Fans	2.0%	1.9%	1.9%	2.0%	2.0%
Personal Computers	0.3%	1.4%	1.6%	1.9%	2.0%
Clothes Washers	0.8%	0.8%	0.8%	0.7%	0.7%
Dishwashers	0.6%	0.6%	0.5%	0.5%	0.5%
Other Uses	24.0%	26.4%	28.2%	34.9%	37.9%
Total Electricity	100.0%	100.0%	100.0%	100.0%	100.0%

Source: EIA Annual Energy Outlook 2001

While it would be ideal to characterize Missouri building energy consumption using state-specific data, such data is largely not available in the public domain and would need to be developed from surveys or existing proprietary sources. In the absence of Missouri-specific data and in view of budget and modeling tool constraints, the present study assumes that average end-use shares of energy consumption in the Missouri building sectors are the same as national averages and relies on data from EIA, the Census Bureau and other national or regional sources to characterize state energy use in these sectors.

Technical Potential for Reductions

How much could energy use be reduced by promoting energy efficiency? A number of studies have attempted to estimate this. For example:

- The 1997 study *Energy Innovations*, published by five organizations involved in advocating efficiency (Alliance to Save Energy, American Council for an Energy Efficient Economy, Natural Resources Defense Council, Tellus and Union of Concerned Scientists) estimated that “Innovation Path” programs and policies could reduce energy use by about 17 percent.
- One ENERGY STAR® information resource available to residential consumers is an online tool that provides a rough estimate of energy savings possible from adopting ENERGY STAR upgrades in his or her residence. The application provides estimates of upgrade cost, annual and lifetime cost savings, return on investment, payback period and appliance management recommendations for each recommended upgrade. The application allows the consumer to provide detailed input about energy use but, as a default, relies on statistics gathered from EIA’s triennial residential energy consumption surveys and technical data on average efficiencies in various energy use categories.

A Department of Natural Resources’ Energy Center estimate using this tool indicates that an “average” Missouri residence could reduce its annual utility bill by as much as 47 percent through a combination of building shell upgrades and equipment replacements. The appliance replacements would include a programmable thermostat, an energy-efficient water heater and an ENERGY STAR labeled air conditioner, furnace, clothes washer, windows, dishwasher and refrigerator.

- In 1998, the Energy Cost Savings Council, in conjunction with Energy User News, analyzed over 1,000 facility upgrade projects documented from 1988 to 1996, involving one or some combination of increased energy-efficient lighting, motors, drives, building automation systems, or heating, ventilation, and air conditioning (HVAC) systems. That study showed

that companies can save up to \$1.00 per square foot in annual operations costs, obtain a 30 to 50 percent return on investment within two to three years of initial investment and enjoy savings over a 10- to 20-year average product life cycle. Projections of this data suggest that “corporate America has an opportunity to reduce energy costs by \$50 billion to \$100 billion via energy-efficient electrical product upgrades.” (Source: Simple Steps to Energy Savings reprinted on Facility Management Magazine website, www.facilitymanagement.com/articles/index.html).

We rely here on two recent estimates from U.S. Department of Energy (U.S. DOE) sources that were published in November-December 2000 – EIA’s Annual Energy Outlook 2001 and the study *Strategies for a Clean Energy Future*, prepared by a group of five federal energy laboratories (in subsequent references: 5-lab study). These sources provide estimates of the potential reduction in residential and commercial energy from implementing available and foreseeable energy-efficient technologies.

The two studies necessarily take a long-term perspective because many potential improvements would only be adopted as old equipment is replaced. Reductions are compared to a business-as-usual reference case. The business-as-usual case itself incorporates a limited increase in energy use efficiency due to anticipated penetration of more efficient technologies.

In order to project CO₂ emissions based on projections of electricity use, it was necessary to assume that the mix and efficiency of generating sources in Missouri would remain unchanged during the projection period. Total CO₂ emissions would decrease if this mix changed through factors such as:

- An increase in the efficiency of coal-fired plants, for example, through the deployment of “clean coal” technologies.
- A decrease in their share of total generation, for example, through the proliferation of natural gas fired plants.

Alternatively, total CO₂ emissions would increase if the mix changed through such factors as:

- An increase in reliance on coal-fired plants, for example, through retirement of the Callaway nuclear plant.
- A decrease in their average efficiency, for example, through delaying the retirement of old plants.

Residential Sector

Missouri’s residential sector consumed about 27.6 billion kWh of electricity and 112 trillion Btu of natural gas in 1999.

Assuming that residential electricity use in Missouri grows at the same rate as that projected for the United States in EIA’s AEO 2001 baseline case, consumption of electricity in the sector would increase by about 27 percent between 1999 and 2010 and by 48 percent between 1999 and 2020.

Similarly, residential natural gas consumption would increase by about 17 percent between 1990 and 2010 and by 30 percent between 1999 and 2020.

The 5-lab study analysis allows comparison of this business-as-usual case to a case including all “techno-economic potential” for reductions through efficiency improvements. Table 9 (attached) combines projected CO₂ emissions from residential electricity and natural gas end uses based on EIA AEO 2001 with the 5-lab estimates of techno-economic potential. The projections assume that Missouri end use distribution and growth rate is identical to EIA projections for the United States for these years, and that 5-lab study projections of techno-economic potential for the United States as a whole can be applied to Missouri.

As Table 9 indicates, the 5-lab study estimated potential to reduce energy use and emissions for each end use. Applying these estimates to the Missouri projections, it is possible to conclude that EE/RE measures could reduce CO₂ emissions from electricity use by about 9.4 million tons in 2010 compared to business-as-usual projections, and 14.5 million tons in 2020 compared to BAU. The corresponding reductions in natural gas use are 0.4 million tons in 2010 and 1.0 million tons in 2020. One reason for the lower reductions in natural gas is that the 5-lab study assumes that some fuel will switch from electricity to natural gas.

Commercial Sector

The same methodology used to project business-as-usual residential sector emissions and the techno-economic potential to reduce these emissions can also be applied to the commercial sector. As with the residential sector, the projections assume that Missouri commercial end use distribution and growth rate is identical to EIA projections for the United States for these years. Table 10 (attached) presents the results of this analysis.

Assuming that residential electricity use in Missouri grows at the same rate as that projected for the United States in EIA’s AEO 2001 baseline case, consumption of electricity in Missouri’s residential and commercial sectors would increase by about 27 percent and 32 percent, respectively, between 1999 and 2010 and by 48 percent and 52 percent, respectively, in 2020.

Corresponding projected increases for natural gas consumption would be 17 percent (residential) and 23 percent (commercial) for 2010, and 30 percent (residential) and 31 percent (commercial) for 2020.

A 2.7 percent business-as-usual AARG in CO₂ emissions from electricity use is projected for the period 1990-2010. For the period between 1990 and 2020, the business-as-usual AARG rate is 2.3 percent. Corresponding business-as-usual growth rates for natural gas are 1.3 percent through 2010 and 1.1 percent through 2020. As previously noted, such a substantial rate of growth presents a major challenge to achieving goals such as the Kyoto Protocol goal of reducing future emissions below 1990 levels.

As shown in Table 10, the 5-lab study estimated potential to reduce energy use and emissions for each end use. Applying these estimates to the Missouri projections, it may be concluded that EE/RE measures could reduce CO₂ emissions from electricity use by about 6.0 million tons in 2010 compared to business-as-usual projections, and 9.4 million tons in 2020 compared to BAU.

The corresponding reductions in natural gas use are 0.7 million tons in 2010 and 1.3 million tons in 2020. One reason for the lower reductions in natural gas is that the 5-lab study assumes that some fuel will switch from electricity to natural gas.

Technical Potential Versus Achievable Potential

One conclusion from the above analysis is that the potential exists through cost-effective EE/RE measures to reduce CO₂ emissions from Missouri electricity use in 2010 and 2020 below the current (1999) level of emissions. Specifically, if all potential efficiencies were realized, there could be a 6 percent reduction over 1999 levels in 2010 and a 9 percent reduction in 2020.

However, it is a premise of the 5-lab study that market penetration of efficient technologies cannot achieve 100 percent. An earlier 1997 study estimates the percentage of “technoeconomic potential” that might actually be achieved through policies to promote implementation of EE/RE measures beyond those that would be achieved anyway under baseline assumptions. The analysts involved in developing the report went through an elaborate process to estimate achievable potential, explicitly characterizing pathways for specific policies under two scenarios, a “moderate” scenario of less controversial policies and an “advanced” scenario containing more aggressive and potentially controversial policies such as a carbon cap-and-trade program.

Table 11 presents the 5-Lab study’s estimates of the percentage of “technoeconomic potential” reductions that could be achieved in the residential sector under these two scenarios in 2010 and 2020.

Table 11: Estimated Percentage of “Technoeconomic Potential” for Energy Efficiency that Could be Achieved in the Building Sectors by Implementing the “Moderate” and “Advanced” Scenarios through 2010 and 2020

	Through 2010		Through 2020	
	Moderate	Advanced	Moderate	Advanced
Residential				
Electricity	28%	34%	45%	65%
Natural Gas	21%	28%	22%	36%
Commercial				
Electricity	37%	42%	54%	62%
Natural Gas	22%	29%	25%	40%

Tables 12 and 13 (attached) show the result of applying these percentages to business-as-usual and “technoeconomic potential” projections developed for Missouri residential buildings.

As was noted in Table 4, very large business-as-usual increases are projected for emissions from energy use in Missouri’s residential sector between 1990 and the target dates of 2010 or 2020. The “achievable” reductions under the moderate and advanced scenarios represent large reductions in emissions from electricity use; however, in no case do the reductions achieve a

return to 1990 emission levels. Table 14 indicates the potential dampening effect of the various 5-Lab scenarios on CO₂ emissions increases that are otherwise projected to occur.

Table 14: Percentage Increase in Missouri Residential CO₂ Emissions Under 5-Lab Study Scenarios, Compared to “Business-as-Usual” Reductions

	2010		2020	
	Moderate	Advanced	Moderate	Advanced
Electricity	49% (vs 62%)	47% (vs 62%)	58% (vs 90%)	44% (vs 90%)
Natural gas	11% (vs 12%)	11% (vs 12%)	21% (vs 24%)	19% (vs 24%)

Tables 15 and 16 (attached) show the results of applying the percentages in Table 11 to the commercial sector. As with the residential sector, in no case do the “achievable” reductions under the moderate or advanced scenarios reduce total emissions to a 1990 level.

Comparing the projected increases in Tables 12-13 and 15-16, it may be concluded that a reasonable target for EE/RE policies is to set a goal of dampening the emissions increases that are otherwise projected to occur, using current (1999) emissions as a reference point.

End Uses with Greatest Technical Potential for Reductions

Tables 17a and 17b show the residential end-uses with greatest potential for energy and emissions savings through EE/RE and incorporates a similar analysis based on the EIA AEO 2001 best-technology scenario. Based on comparison of potential percentage reduction of different end uses, the end uses with greatest potential for achieving emission reductions are lighting, water heating and space cooling. A similar analysis of the commercial sector indicates that lighting and space cooling are the most promising areas for EE/RE policies.

Table 17a: EIA 5-Lab and AEO 2001 Estimates of Technical Potential to Reduce Projected Business-as-Usual Residential Electricity Consumption Through Efficiency, by End Use Sector

	U.S. Consumption (Quad Btu)			U.S. Consumption Billion kWh (U.S.)			
	1999	EIA BAU	EIA Effic	1999	EIA BAU	5-Lab Effic	EIA Effic
Space Heating	0.38	0.51	0.39	111.3	150.2	124.71	114.3
Space Cooling	0.52	0.77	0.50	152.0	225.7	164.79	146.5
Water Heating	0.39	0.43	0.13	115.5	126.9	88.82	38.1
Refrigeration	0.43	0.33	0.29	125.1	95.3	65.75	85.0
Cooking	0.10	0.13	0.13	29.9	38.8	34.50	38.1
Clothes Dryers	0.22	0.29	0.28	63.3	84.9	67.96	82.1
Freezers	0.12	0.09	0.08	34.5	25.7	20.27	23.4
Lighting	0.34	0.52	0.32	99.5	152.0	55.48	93.8
Clothes Washers	0.03	0.04	0.02	8.6	11.2	5.62	5.9
Dishwashers	0.02	0.03	0.01	6.2	8.1	8.06	2.9
Color Televisions	0.12	0.24	0.24	35.5	69.9	52.46	69.9

Personal Computers	0.06	0.11	0.09	18.8	33.5	33.51	26.4
Furnace Fans	0.07	0.12	0.11	21.8	33.9	8.47	32.2
Other Uses	1.10	2.20	2.20	323.5	644.8	333.17	644.8
Total Electricity	3.91	5.80	4.80	1,145.7	1,701.0	1,071.64	1,406.8

Table 17b: Projected Reduction (Percentage) and Growth Rate Comparison for 5-Lab and EIA Efficiency Scenarios Compared to Residential Business-as-Usual Projections from Table 17a

	% reduction 2020		Ave. annual growth rate		
	5-lab	EIA effc	BAU	5-lab	EIA effc
Space Heating	17%	24%	1.7%	0.5%	0.1%
Space Cooling	27%	35%	1.7%	0.4%	-0.2%
Water Heating	30%	70%	0.9%	-1.2%	-5.1%
Refrigeration	31%	11%	-0.4%	-3.0%	-1.8%
Cooking	11%	2%	1.5%	0.7%	1.2%
Clothes Dryers	20%	3%	1.6%	0.3%	1.2%
Freezers	21%	9%	-0.5%	-2.5%	-1.8%
Lighting	64%	38%	2.1%	-2.7%	-0.3%
Clothes Washers	50%	48%	1.5%	-2.0%	-1.8%
Dishwashers	0%	64%	1.5%	1.2%	-3.5%
Color Televisions	25%	0%	3.1%	1.9%	3.3%
Personal Computers	0%	21%	8.8%	2.8%	1.6%
Furnace Fans	75%	5%	2.1%	-4.4%	1.9%
Other Uses	48%	0%	3.7%	0.1%	3.3%
Total Electricity	37%	17%	2.2%	-0.3%	1.0%

Advanced Building Technologies

The 5-Lab study's analysis of technoeconomic potential and the EIA AEO analysis of its best-case efficiency scenario do not attempt to take into account some leading-edge building technologies. These technologies represent a "wild card" factor in the potential for reducing CO₂ emissions.

Despite the importance of the housing industry, U.S. expenditures on residential technology research and development are relatively low as a percentage of sales compared to other industries and in comparison to other industrialized countries. Emerging technologies find difficulty in penetrating the housing market because the construction industry is extremely dispersed, consisting of hundreds of thousands of separate companies. Introducing or achieving market penetration for a new technology in this marketplace is a time-consuming and costly process. It can take 10 to 25 years for a new housing product or technique to achieve full market penetration.

The Partnership for Advancing Technology in Housing (PATH) is a public/private initiative intended to identify, demonstrate and increase the market penetration of advanced building technologies. The PATH partnership has identified dozens of innovative technologies with energy, environmental, quality and durability benefits. According to PATH, by 2010 these technologies should be able to achieve sufficient market penetration to cut the environmental

impact and energy use of new housing by 50 percent or more and reduce energy use in at least 15 million existing homes by 30 percent or more.

The PATH Web site lists innovative materials, products and systems identified by PATH as having energy-efficiency benefits and currently achieving less than 5 percent of their potential market share. The site provides detailed descriptions of achievable cost and energy savings and other potential benefits from adopting these technologies.

Policy Options

The following discussion of state policy options to reduce GHG emissions from energy use in buildings focuses on four categories that appear most promising:

- Energy information and education.
- Energy standards and codes.
- Initiatives targeted at reducing energy use in public-sector buildings.
- Initiatives targeted at increasing voluntary adoption of energy-efficient and renewable energy technologies in the residential sector.

Several of the initiatives discussed – particularly education and information, standards and codes and promotion of the ENERGY STAR label – apply equally to the residential and commercial sectors. However, there is no section specifically devoted to state incentive programs to increase voluntary adoption of energy-efficient and renewable energy technologies in privately owned commercial buildings. However, unless there is a major increase in resources for incentive programs, available resources must be targeted, and the recommendation of this report is that for practical reasons, state incentives should be targeted to the residential sector.

Should the state wish to pursue an incentive program targeted at the commercial sector, most of the considerations that apply to residential incentive programs would also apply to commercial programs. However, program design must take into account that the commercial sector is much more heterogeneous than the residential sector.

The first half of this chapter, on technology options in buildings, focuses on identifying cost-effective energy-efficiency and renewable energy options available that, if adopted, would reduce greenhouse gas emissions in the building sector. The remainder of this chapter, on policy options, addresses the issue of what the state can do to help assure that this technical potential is realized and that market transformation occurs.

Market transformation is a process whereby energy-efficiency innovations are introduced into the marketplace and, over time, penetrate a large portion of the eligible market. The difference between market transformation (MT) initiatives and traditional demand-side management (DSM) is primarily one of focus. Traditional DSM programs have focused on acquiring energy efficiency on a customer-by-customer basis. Market transformation focuses on achieving lasting market effects by addressing different market participants.

The process of achieving lasting market effects can be visualized as occurring in three stages that, if graphed, would resemble an S-shaped curve. An initial, relatively flat period of early adoption would be followed by a sharply rising period of market penetration as the awareness of the new technology and its advantages grows and as it is increasingly made available in the marketplace. Finally, the curve would flatten again as the innovation reaches full market potential. The purpose of market transformation is to move a new technology into the second stage of market penetration. If there is sufficient adoption by consumers, vendors and manufacturers, there should be lasting change in the market.

It is clear that market transformation does take place. For example, the average efficiency of new refrigerators (measured in terms of refrigerated volume per kWh per year) increased by 175 percent during 1972-93. The fraction of windows sold with two or more glazings also increased, from 37 percent of the market in 1974 to 87 percent of the market in 1991.

The rationale for market transformation initiatives is the same as the rationale for energy-efficiency improvements. Put simply, it often costs less to save energy than to supply energy. Thus economic productivity and economic efficiency improve as energy efficiency increases. In addition, air pollution emissions, including emissions of carbon dioxide and other greenhouse gases, decline as end-use energy efficiency rises.

If energy efficiency measures are cost-effective, it is reasonable to ask why they are not widely implemented in the marketplace without policy and program intervention. In other words, why are market transformation strategies needed at all?

The answer to these questions is that barriers such as lack of awareness or information, limited product availability, perceived risks, different parties purchasing equipment and paying operating costs, energy price distortions and limited access to capital inhibit widespread and full implementation of cost-effective energy efficiency measures. These barriers are discussed in detail in STAPPA/ALAPCO, the 5-lab study and other studies.

It is important to recognize that overall energy use depends on equipment stocks, activity levels and consumer behavior as well as the efficiency of appliances, buildings, vehicles and other devices. Market transformation goes beyond simply considering the energy efficiency of new products to involve the people who install and use these technologies. In some cases, proper installation and use is critical to ensure that “efficient” technologies perform up to their full potential.

Adoption and diffusion of building energy-efficiency technologies is a complex and dynamic phenomenon involving interactions between technology, behavior, market conditions and public policy. Decisions affecting energy efficiency are made by manufacturers, vendors, architects, builders, contractors and consumers. New appliance models are introduced every year. Manufacturer and consumer behavior is affected by events such as energy price swings or environmental concerns. Markets vary in terms of prices, growth rates, competition and other factors. A wide range of policies or programs, including energy-efficiency educational efforts, financial incentives or regulations, is possible.

This complexity makes it difficult to estimate market response to specific action options, particularly options such as those discussed in this report, that are based on voluntary consumer actions rather than mandates. The 5-lab study approached this issue by applying “our best qualitative judgment, based on our collective experience with buildings efficiency programs, because there is simply no ‘scientific’ means for predicting the precise impact of most policy measures.” (p. 4.15)

After an exhaustive literature survey, the authors of the Pew Center’s study *Appliances and Global Climate Change* concluded that:

There is no solid foundation for estimating the percentage of consumers who will change their purchasing decisions or choose to retire appliances in response to changes in energy prices, improvements in appliance efficiency, incentives or other programs...Until additional research is available, policy-makers can only make educated estimates of the probable level of consumer response to an energy-efficient appliance incentive or education program. (p. 4)

The selection of action options presented in this chapter attempts to adhere to the request by the project’s steering committee to analyze options that are politically feasible. Nonetheless, the nature of several of the options would rely on political decisions with very uncertain outcomes.

Therefore, rather than attempt to estimate and aggregate outcomes from the policy options, this study sets a target for emissions reductions from the building sector. The target is extrapolated from the 5-lab report’s estimates of “moderate scenario” reductions for the United States. This estimate, based on expert judgment and explicit characterization of end uses and policies, appears to be the best-available estimate of the level of GHG reductions available under a politically feasible scenario.

Energy Information and Education

Energy information and education are essential components of most of the action options described in this chapter, including all voluntary programs directed at increasing energy efficiency and renewable use in public and residential buildings.

Appliance standards and energy codes also rely on effective dissemination of energy information and education to meet their larger goals. Standards and codes, even if they are mandatory, are not likely to succeed without informed, willing compliance. Furthermore, the larger role of standards and codes as a baseline for defining higher efficiency standards is essentially informational and educational in nature.

To avoid needless repetition, this chapter’s discussion of energy information and education is confined to the following section, although every section in the chapter could legitimately include a discussion of this topic.

Background

Providing energy-related information is part of the mission of the Missouri Department of Natural Resources' Energy Center . The center provides state leaders and the public with data, information and analysis of energy use, sources, prices, supply and air emissions related to energy production and use; and disseminates consumer and technical energy information to inform the public about opportunities in energy efficiency and renewable energy. The center has contributed exhibits and information for local events such as Clean Cities, town meetings, Earth Day, the State Fair, solar car races, solar home tours and many others. It has also entered into cooperative agreements to support substantive programs such as the Gateway Center for Resource Efficiency (GCRE), Rebuild America and the Pattonsburg relocation project.

Examples of other organizations that promote energy education in Missouri include a number of K-12 school systems and Missouri-based not-for profit organizations such as GCRE and the Metropolitan Energy Center (MEC). GCRE, through its cooperative agreement with the department's Energy Center, has networked with local school districts to provide the most currently available energy-efficiency information. Kansas City-based MEC has made energy-related information available to Missourians, addressing policy, economic, technical and consumer issues that affect their daily lives.

The Energy Futures Coalition's final report details many additional ongoing energy information and education efforts by public and private entities in Missouri, including other state agencies and universities, schools and local governments, not-for-profit organizations, utilities and other businesses.

Action Options

As recommended by the Missouri Statewide Energy Study (MSES) and the Energy Futures Coalition (EFC), Missouri should organize activities to promote an increase in the general awareness and appreciation of energy resource issues and should develop a coordinated, accessible public energy information network linking diverse, reliable information sources. This initiative, while not limited to energy issues related to energy use in buildings, should:

- Provide access through appropriate communication media to reach all owners or managers of buildings in the state, whether public, commercial or residential.
- Compile, create and disseminate quality consumer and technical information about energy-efficient technology and management in buildings.
- Expand the base of public information about current and potential use and sources of energy in Missouri's building sectors by supporting quality economic, environmental and other building energy-related data collection, analysis and reporting.
- Specifically support energy-efficiency education for low-income residential consumers.

As recommended by the EFC, Missouri should develop and support a public education curriculum that promotes energy literacy. The curriculum should include a basic understanding of the role and impact of energy production and use in the building sector.

Finally, as recommended by both MSES and the EFC, the state should encourage the development of promotional and recognition programs for energy efficiency in both the public and private sectors. Recognition programs should include both state-specific efforts, such as the Governor's Energy Award program recommended by the EFC, and partnerships with federal and regional programs such as ENERGY STAR.

Standards and Codes

This report emphasizes voluntary no-regret actions to reduce state GHG emissions. Accordingly, this chapter emphasizes efforts to influence voluntary adoption of energy efficiency and renewables by building owners based on reliable technical information, market forces and Missouri citizens' desire to contribute to the public good.

Several mandatory approaches to energy efficiency are also widely accepted in the United States as appropriate and effective means to advance the public good. The federal government sets minimum efficiency and labeling standards for manufactured equipment, and state energy codes are in wide use in throughout the United States. These measures help ensure that the public will benefit from technological progress and also establish a benchmark for voluntary labeling programs, such as Home Energy Rating Systems (HERS) and ENERGY STAR, that define additional cutting-edge opportunities for energy efficiency.

Federal Appliance Standards and Energy Labels

Background

National energy-efficiency standards were established between 1987 and 1992 by the National Appliance Energy Conservation Act (NAECA) and the Energy Policy Act (EPAAct). The NAECA, enacted in 1987 and amended in 1998, mandates minimum energy-efficiency requirements for 12 types of residential appliances sold in the United States: refrigerators, refrigerator-freezers, freezers, room air conditioners, fluorescent lamp ballasts, incandescent reflector lamps, clothes dryers, clothes washers, dishwashers, kitchen ranges, ovens, pool heaters, television sets (withdrawn in 1995) and water heaters. EPAAct, enacted in 1992, mandates additional standards for some fluorescent and incandescent reflector lamps, plumbing products, electric motors, commercial water heaters and HVAC systems.

Energy-intensive appliances that are not regulated by either act include distribution transformers, coin-operated washing machines, refrigerated vending machines and portable lamps such as halogen torchieres.

The NAECA and EPAAct provided a timetable for U.S. DOE to promulgate increasingly stringent efficiency standards. Revised standards are supposed to achieve the maximum level of technically feasible, economically justifiable savings. Revision of appliance standards can serve as an instrument for market transformation.

For example, a new fluorescent lighting standard due to be implemented April 1, 2005, is expected to transform a market currently dominated by 1.5-inch-diameter T12 lamps using magnetic ballasts to one dominated by lamps with more efficient electronic ballasts. This

upgrade, like other appliance standard revisions, resulted from years of discussion between U.S. DOE, manufacturers of lighting equipment and efficiency advocates.

Electronic ballasts are more expensive than magnetic ballasts, but their higher efficiency reduces total life cycle cost. According to an analysis conducted by the Lawrence Berkeley Laboratories Environmental Energy Technologies Division (EETD), switching to an electronic ballast yields, on average, a savings of \$6 in life cycle costs; switching to 1-inch-diameter T8 lamps using electronic ballasts saves, on average, \$18 over the life of the investment.

The EETD analysis estimates that the switch to electronic ballasts will result in cumulative energy savings of 2 to 5 thousand trillion Btu of primary energy between 2005 and 2030. For comparison, total energy use in Missouri is just below 2 thousand trillion Btu per year. Businesses will reduce electricity costs by \$3.4 to \$7.2 billion; taking the higher initial cost of electronic ballasts into account, estimated net savings to businesses will range from \$2.6 to 5.4 billion. (EETD Newsletter, Winter 2000).

In addition to serving as a driving force for investment and innovation in the U.S. appliance industry, national energy-efficiency standards have significantly reduced CO₂ emissions from energy use.

The Appliance Standards Awareness Project (ASAP) estimates that the appliance standards put into effect between 1987-92 reduced total national energy consumption in 2000 by about 1.2 quadrillion Btu, equivalent to the annual energy use of about 6.5 million American households, and cut U.S. CO₂ emissions in 2000 by 108 million short tons, an amount equal to Missouri's total CO₂ emissions from fossil fuel combustion in 1990. According to the EETD analysis, the new ballast standard will reduce CO₂ emissions between 2005 and 2030 by 120 to 280 million tons.

The fluorescent ballast revision, which was delayed nearly ten years past its original 1992 due date, is one of four recent revisions announced during the past year. The other three new revisions are for water heaters (also originally due in 1992), central air conditioners and heat pumps (originally due in 1994) and clothes washers (originally due in 1995). Prior to the year 2000, U.S. DOE upgraded only two standards, for room air conditioners (effective October 1, 2000) and for refrigerators and freezers (effective July 1, 2001).

In a report published shortly before the newest announcements were made, ASAP projected the economic, energy and emissions impact of revising these four standards plus three others for transformers, commercial air conditioning and commercial heating equipment. ASAP estimated that revision of the seven standards could, by 2020, produce an additional 1.8 quads of energy savings with net economic benefits exceeding \$40 billion and annual carbon emissions reductions of 115 million tons of CO₂. [www.standardsasap.org]

Action Options

- As noted above, U.S. DOE recently announced revisions of federal energy-efficiency standards for clothes washers, water heaters, fluorescent lighting and central air conditioners and heat pumps. The state could express its support for U.S. DOE's expeditious implementation of these revisions, which, according to federal legislature, were originally

due to be announced in 1992-1995. According to an analysis by ASAP, by 2020 the four new standards, in addition to reducing CO₂ and other emissions from power plants, will save U.S. consumers and businesses \$25 billion net during 2004-2030 and will reduce peak electric demand in the United States by 54,000 MW.

- The state could express its support for U.S. DOE's expeditious announcement and implementation of three more overdue revisions of federal standards for transformers, commercial air conditioning and commercial heating equipment. According to an ASAP analysis, these revisions, together with the four revisions recently announced, could produce electricity savings of 2.8 billion kWh and primary energy savings of 36 trillion Btu in Missouri, save Missourians \$846 million and reduce the state's CO₂ emissions by about 2.2 million tons. Furthermore, the three overdue standards would help to moderate the growth of energy use in Missouri's commercial sector, the sector of most rapid growth in electricity use and a sector where energy use is not readily influenced by state voluntary initiatives and incentives.
- Mandatory label standards that apply to all manufacturers or vendors of energy-using equipment and appliances are a critical component of any effort to promote voluntary end user choice of cost-effective energy efficient appliances and equipment. Informative, consistent, easily comprehended energy labels provide point-of-sale information that permits the end user to take energy savings into account when comparing alternative investments and to estimate the payback from investing in energy efficiency.
 - The state should express its support for continued federal appliance energy labeling requirements that are at least as detailed and informative to the consumer as current requirements.
 - As recommended by the EFC, the state should build on federal energy labeling provisions to support a voluntary national effort for improved energy-efficiency labeling of appliances.

Building Energy Codes

Background

The Missouri Energy Futures Coalition recommended in 1997 that "Missouri should adopt building codes ... that establish cost-effective minimum energy-efficiency standards for new residential and commercial facilities." The EFC report also recommended the development and promotion of "voluntary building standards that promote aggressive methods for improving energy efficiency and environmentally sound building design" that exceed these minimum standards.

Energy codes set minimum efficiency standards for energy use in buildings. Rather than specify the precise construction technologies or systems that must be employed in new buildings, they set a reasonable level of energy consumption based on reviewing a broad range of available options. According to numerous analyses, establishing and complying with appropriate energy standards is one of the surest available ways to realize the benefits of advances in building energy use technology.

For example, a 1998 study by the Alliance to Save Energy (ASE), *Opportunity Lost: Better Codes for Affordable Housing and a Cleaner Environment*, analyzed the impact of adoption of a mandatory residential code, the Council of American Building Officials (CABO) 1993 Model Energy Code (MEC), in states where residential codes are currently less stringent. The analysis found that adoption would result in annual savings to American homebuyers of \$81 million and the reduction of 7 trillion Btu in energy use and approximately 226 thousand tons of air pollutants per year. The analysis also found that for the typical home-buyer, monthly mortgage payments would increase slightly as a result of adoption, but savings on energy bills would increase more, resulting in a net increase in cash flow and making home ownership more affordable for the typical buyer.

While the specific residential code cited in the ASE study has been superseded, the analysis illustrates that implementation of energy codes can be expected to result in energy-efficiency gains that benefit both to owners of residential and commercial buildings and the general public. The resulting energy efficiency reduces air emissions and also relieves pressure on electricity, natural gas and other energy supplies.

States that have adopted energy codes for commercial buildings have most frequently used standards produced by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). For residential buildings, they have most frequently used the CABO MEC standards. These standards have been periodically updated by ASHRAE and CABO to take account of changes in the building industry and new cost-effective opportunities for efficiency. For example, in 1995 CABO updated its Model Energy Code by increasing wall and ceiling insulation, increasing duct sealing and insulation, limiting heat loss through recessed-lighting fixtures, changing allowable air leakage rates for windows and sliding doors and correcting thermal calculations with metal-stud framing.

A study conducted for HUD in 1997 by the Pacific Northwest National Laboratory, *Assessment of the 1995 Model Energy Code for Adoption*, concluded that moving to the 1995 standard from the previous version of the MEC would be economically justified because it would create “significant savings for homeowners [and] a significant increase in energy efficiency.”

More recently, these standards have been updated and incorporated into the International Energy Conservation Code (IECC), which is part of a family of codes developed by the International Code Council. The 2000 International Energy Conservation Code covers energy-efficiency provisions for residential and commercial buildings, prescriptive- and performance-based approaches to energy-efficient design and building envelope requirements for thermal performance and air leakage.

In 1999, the Missouri Governor’s Commission for the Review and Formulation of Building Code Implementation recommended that “the family of International Codes published by the International Code Council should be established by law as the code for use by design professionals in areas where local codes do not exist [and] ... should be the codes adopted when those areas that currently do not have building codes decide to adopt codes.” Thus, the IECC could be considered to supersede the specific standards recommended by the Energy Futures Coalition (the CABO energy code for residential buildings and the ASHRAE 91.1-1989 energy standards and subsequent upgrades for commercial buildings).

Two previous reports have recommended that Missouri adopt statewide energy codes. In 1992, the *Statewide Energy Study* recommended that Missouri adopt the current ASHRAE and CABO MEC standards as consensus minimum performance standards for commercial and residential buildings. *The Energy Study* recommended that these should be adopted as mandatory codes if voluntary compliance had not been achieved within 5 years (1997).

In 1993, the HCR16 report recommended that Missouri should establish state-specific residential and commercial energy standards equivalent to the current ASHRAE and CABO MEC standards. The HCR16 report stated reservations with respect to adopting the specific ASHRAE and CABO MEC standards prevalent at the time. The study offered recommendations for adopting equivalent standards tailored to Missouri-specific requirements and intended to provide the same efficiency benefits while providing more flexible compliance paths.

Both the *Energy Study* and the HCR16 report projected significant macroeconomic benefits from adopting statewide energy codes. The *Energy Study* estimated that every \$1 million spent complying with the ASHRAE 90.1 energy code would create about a half million dollars in net income, about 27 net jobs and have a simple payback of about 4 years. Every \$1 million spent complying with the CABO residential code would create about \$320 thousand in net revenue, 16 net jobs and have a simple payback of about 6 years.

The HCR16 study estimated environmental and macroeconomic benefits to be achieved from implementing three different levels of energy standards for new residential and commercial buildings – the MEC and ASHRAE standards, a higher standard based on recommendations by utilities and builders associated with energy-efficiency efforts in the state, and a third very aggressive level of efficiency improvements. Estimates of benefits for the three levels were based on detailed examination of prevailing and available energy technologies for specific end uses in a number of building types.

The HCR16 study concluded that implementation of standards at any of the three levels would provide a net macroeconomic benefit compared to the baseline case of no energy standards. The estimated net benefits for the three levels of implementation were about \$110 million from implementing the MEC and ASHRAE standards, \$550 million from implementing the “recommended” and \$490 million, respectively, suggesting that the maximum benefit to society could be achieved with standards set higher than the MEC and ASHRAE standards. Accordingly, the HCR16 report recommended rating, incentive and other programs to encourage and reward implementation of energy efficiency greater than the minimum standards in state energy codes.

Missouri has established minimum efficiency standards for state buildings pursuant to legislation passed in 1993. State-owned residential buildings less than three stories high must conform to the latest editions of the CABO MEC or American National Standards Institute (ANSI)/ASHRAE Standard 90.2-1993. Other state-owned buildings must conform to ASHRAE/IESNA (Illuminating Engineering Society of North America) 90.1-1989. New editions/revisions to these standards are automatically adopted by reference. The standards cover new state buildings (or portions), additions, substantial renovations, or existing buildings considered for lease (when over 10,000 sq. ft.) or acquisition by the state. Compliance for state-funded buildings is demonstrated through plan review and inspections by the Missouri Office of

Administration, Division of Design and Construction. (10 CSR 140-7, Department of Natural Resources.)

However, with the exception of requirements for state buildings, Missouri has not established statewide building or energy codes. Local cities and jurisdictions adopt their own building and energy code requirements. Compliance at the local level, if any, is through plan review and inspection by local building officials.

Missouri localities with building codes have in most cases adopted the Building Officials and Code Administrators (BOCA) International National Building Code (NBC). Some localities in the western part of the state have adopted the International Conference Building Officials (ICBO) Uniform Building Code (UBC), and a few localities in the southeast use the Southern Building Code Congress International (SBCCI) Standard Building Code (SBC).

A 1994 survey of localities by the Missouri Department of Natural Resources' Energy Center indicated that cities and counties with building codes in place represented 47 percent of the state's population. Those without codes represented approximately 28 percent of the population. The remaining localities, representing 25 percent of the population, did not respond to the survey.

As described above, the *State Energy Study*, HCR16 report and *Energy Futures Coalition* report have all recommended that Missouri adopt statewide residential and commercial energy codes. About two-thirds of U.S. states, including seven of the eight states neighboring Missouri, have adopted mandatory statewide energy codes for new residential and commercial buildings. (Building Code Assistance Project)

One indicator that energy codes are a significant state policy option to deliver greenhouse gas reductions is that the tightening of energy codes is included as an important policy measure in most climate change action plans completed by states under U.S. EPA sponsorship, both for states that have existing codes and those that do not. (U.S. EPA state plan database). In Missouri, where no statewide code exists, the option of enacting energy codes could be considered "low-hanging fruit" on the tree of state options to reduce greenhouse gas emissions.

Other indicators are contained in findings of the 1998 ASE study, *Opportunities Lost*. The study compares the impact by state of implementing a residential energy code based on the MEC '93 standard. The study ranked Missouri fifth among all states in potential for annual statewide energy savings (567 billion Btu) and energy savings per home (20.8 million Btu) that could be derived from establishing a state energy code. The study ranked Missouri as one of the top three states for total potential reductions in air pollution. Finally, the study estimated that within 1.5 years the monthly savings per Missouri home would exceed the monthly increase in mortgage payments from implementing measures to be in compliance (Opportunities Lost, page viii and Table L). Because the study was completed in 1998 when energy prices were lower than now, it probably underestimated the economic benefits of action.

Action Options

- As recommended by the Missouri Governor's Commission for the Review and Formulation of Building Code Implementation, "the family of International Codes published by the

International Code Council should be established by law as the code for use by design professionals in areas where local codes do not exist [and] ... should be the codes adopted when those areas that currently do not have building codes decide to adopt codes.”

- As recommended by the Missouri Energy Futures Coalition, the Energy Study and the HCR16 report, Missouri should adopt building codes that establish cost-effective minimum energy-efficiency standards for new residential and commercial facilities. The energy code adopted should be the International Energy Conservation Code (IECC) because it incorporates and supersedes the specific codes standards recommended in 1997 by the Energy Futures Coalition (the CABO energy code for residential buildings and the ASHRAE 91.1-1989 energy standards and subsequent upgrades for commercial buildings).
- Also as recommended by the EFC, the state should develop and promote voluntary building standards that promote aggressive methods for improving energy efficiency and environmentally sound building design that exceeds these minimum standards.
- State legislation should be required to adopt a statewide building or energy code in Missouri. Throughout the United States, adoption of energy codes is frequently subject to high levels of political controversy due to their impact on different private and public sector stakeholders and their varying geographical applicability. Several times during the past decade, legislation to establish a statewide building code has come to a vote in the Missouri legislature and has failed to pass. Should it prove politically impossible to follow the above recommendations, as an alternative to mandatory codes, Missouri could establish non-mandatory energy standards, such as the IECC standard recommended by the 1999 Governor’s Commission, as a target for voluntary compliance and a reference point for energy-efficiency rating and incentive programs. Further, the state could commit itself to a strong campaign to encourage design professionals and local jurisdictions to adopt the standards, particularly (as recommended by the 1999 Governor’s Commission) in areas where no current jurisdiction exists.

Voluntary Programs and Partnerships - Public Buildings

Through the action options described in the preceding section – equipment standards, energy codes and DSM programs operated or financed by the state’s utilities – the state can promote adoption of EE/RE in buildings throughout the commercial as well as the residential sector. For a significant segment of the commercial sector – public buildings – an additional array of tools is available to the state.

Energy Efficiency in State Facilities

Background

State facilities encompass 60 million square feet in more than 5,000 owned state facilities. An additional three million square feet in more than 400 buildings is leased. An analysis of utility bills shows an average utility cost of \$1.11 per square foot. Typically, properly implemented and well-maintained energy projects can be expected to return from 10 percent to 50 percent or more in avoided costs or cost savings over the life of the project.

Average energy savings opportunities identified by state facility audits are 27,602 Btu/square foot, compared to 7,080 Btu /square foot for K-12 school audits. Some possible reasons for larger energy savings opportunities in state facilities are year-round use of state facilities, a greater quantity of office equipment and older buildings.

The Missouri General Assembly established the Energy Efficiency in State Facilities project, authorized by House Bill 195 and Senate Bill 80 in 1993 (Sections 8.800-8.851, RSMo), to reduce state government utility expenditures through encouraging or mandating cost-effective energy efficiencies and renewable energy sources in public facilities.

Working jointly with the Office of Administration (OA) and a Technical Advisory Group of statewide energy experts, the Department of Natural Resources' Division of Energy developed the State Building Minimum Energy-Efficiency Standards, 10CSR 140-7.010, which became effective February 25, 1996. These minimum energy-efficiency standards for new construction and substantial renovation, which were based on latest version of ASRAE 90-1, are managed by the agencies responsible for construction or lease of state buildings, including OA, Department of Higher Education, Department of Transportation and Department of Conservation.

Technical and exploratory energy studies are being completed on 5.4 percent of the current 62 million square feet of owned state facilities. Exploratory audits and technical energy studies provide a comprehensive energy management plan that identifies cost-effective energy conservation measures for implementation. The Energy Center, in conjunction with the Office of Administration's Division of Design and Construction, has completed energy audits for four facilities encompassing 1,381,100 square feet. Building energy audits are underway for an additional four facilities encompassing 1,988,000 square feet. A walk-through audit was also conducted for a 50,700 square foot facility.

The efficiency measures that have thus far been identified are expected to result in the following annual reductions in energy use and emissions:

	Electricity	Natural Gas & other	Total
MMBtu	77,368	40,120	117,488
Carbon Dioxide (CO ₂)	45,336,971	2,198,692	47,535,663
Nitrogen Oxide (NO _x)	194,951	(no data)	194,951
Sulfur Dioxide (SO ₂)	423,905	(no data)	423,905

Energy-efficiency demonstration projects are being implemented in state agencies, including two Department of Mental Health facilities, and the Department of Natural Resources plans to construct Green Building(s).

The Department of Natural Resources plans to erect a Green Building that will eventually house the agency. The Green Building is being designed to demonstrate the environmental and economic benefits of cost-effective design based on principles of sustainable development. The

building will incorporate placement of the structure on the site in relation to the sun to take advantage of passive solar energy; correct sizing and use of energy-efficient heating and cooling systems and appliances; and design of lighting systems, light shelves and glare-free thermal glass to provide daylighting, minimize heat gain and maximize ventilation and shading

The Missouri Office of Administration's Division of Design and Construction established an Energy Services office in June 1995 that is responsible for design compliance with the State's Energy Efficiency Standard; life cycle cost analyses for major energy use capital improvement projects; energy audits of state-owned facilities; implementing the approved energy conservation measures and other energy-use related capital improvement projects; monitoring energy use and cost savings; energy related capital improvement request reviews and other energy use related issues; and building commissioning.

Action Options

- As recommended by the MSES, the state should be a visible leader in successful energy management of its owned and leased buildings.
- As recommended by the EFC, the state should apply life-cycle costing methodologies to the design and/or retrofit of energy systems and buildings and share the lessons learned with other public and private organizations.
- As recommended by MSES, the state should institute state-of-the-art energy accounting systems in its building management and share its example with other public and private organizations.
- As recommended by MSES, energy management should be brought into focus by clearly assigning responsibility for achieving energy-efficiency gains throughout the state. Energy management extends beyond investing in efficient equipment to management of installed equipment to save energy and money while meeting needs. A key role of an energy-management program is energy accounting, monitoring and control. Effective communication and sharing of information between energy managers in the various state agencies is likely to be an important component of achieving this goal.
- As recommended by MSES, the state could incorporate displays of efficient lighting systems into public areas of state buildings.
- The state could develop green buildings to demonstrate advanced building energy management and renewable energy use to other public and private organizations and the general public.
- The State of Missouri is an ENERGY STAR partner. As the state builds a solid record of achievement in efficient energy management in state buildings, it should use ENERGY STAR program resources to promote building energy efficiency among other public institutions in the state.
- As recommended by MSES, if statewide building codes are implemented, all new government buildings owned or leased by the state should adhere to them. In addition, a mandate for increased participation of existing state buildings in the Energy Efficiency in State Facilities (EESF) program could be created by legislation or executive order.

- As recommended by MSES, the state should create incentives for state agencies to expend resources on identifying and implementing energy efficiency in state buildings. State agencies do not share in the energy savings accomplished by these projects. If energy costs are reduced by efficiency measures, the agency's operating budget is likely to be reduced by that amount in the following year's budget. Additionally, state agencies are reluctant to invest time and funds to develop capital improvement requests, because such requests tend to fare poorly, and these energy-efficiency projects compete with the many other priorities facing the agencies. As noted in the background section, recent changes in funding for building audits has created a further disincentive for state agency action.
- As recommended by MSES, the state should change the treatment of savings from successful EESF projects by allowing the agency to retain a portion of the savings in its operating budget or permitting the savings to be redeployed into needed maintenance and repair expenditures.
- The state could establish an audit fund for state building audits to be administered through the Office of Administration Division of Design & Construction (OA/DDC). The first steps in implementing energy-efficiency improvements are a pre-audit evaluation followed, where appropriate, by an audit. In the past, the Energy Center made a half million dollars available for audits. However, this source of funds is no longer available, and an agency would have to find its own funding for an audit. Creation of an audit fund would reduce or eliminate the disincentive of paying up-front for a whole-building audit. Savings from successful EESF projects could be used to pay back the cost of the audit, helping to perpetuate the audit fund.
- The state could consider funding other OA/DDC assistance to agencies to lessen the cost of developing capitol improvement proposals related to EESF.
- To provide an alternative route to achieving the energy savings envisioned in EESF legislation, the state could remove barriers to the use of guaranteed energy savings contracts (GESCs) as a means of implementing energy efficiency in state agency buildings. Legislation passed in 1997 enables agencies to contract for energy services with energy service companies (ESCOs), but thus far no Missouri state agency has done so, although the approach has been successful in other states, such as Indiana. A Missouri state initiative to identify barriers and formulate solutions might originate from the governor's office, the Office of Administration or the state legislature. The National Association of Energy Service Companies (NAESCO) could be consulted to determine the ESCOs' perspective and explore possibilities for collaboration in removing barriers.

Programs and Partnerships to Promote EE/RE in Other Public Buildings

In addition to state government facilities, the public building sector in Missouri includes buildings operated by local governments, K-12 school districts, universities and other higher-education institutions and hospitals with public funding. Total square footage of these public buildings is not known but is substantial. In Missouri, there are 535 high schools, 57 junior high schools, 281 middle schools and 1,276 elementary schools throughout 524 K-12 school districts. In addition, there are 114 county governments, approximately 100 municipal governments serving a population greater than 5000, several state university campuses and 152 hospitals.

A number of these entities have already taken a leadership role in promoting energy efficiency or use of renewable energy. For example, the University of Missouri-Columbia (MU-Columbia) was named the 1997 ENERGY STAR Buildings Partner of the Year in recognition of efforts by its Energy Management office to implement energy efficient lighting retrofits, operational tune-ups and building system upgrades. In 1995, MU-Columbia won the Green Lights University Partner of the Year Award for progress in upgrading lighting, and promoting energy efficiency.

Northwest Missouri State University (NWMSU) currently meets 80 percent of campus heating needs through combustion of waste wood chips and waste paper. Through its commitment to biomass use, the university has helped to create a regional market for waste chips from the wood products industry. This summer, pelletized animal wastes from the university's animal husbandry operations will be added to the stream of waste biomass used for energy. Through this addition, campus officials hope to increase to 85 percent the percentage of campus heating needs met through biomass use. (Personal communication, Nancy Baxter, NWMSU, March 30, 2001).

In conjunction with its focus on enhancing its own building energy management and accounting, the state should promote partnerships, associations and voluntary programs to incorporate leading-edge EE/RE technologies and enhance building energy management and accounting practices in Missouri public institutions, including universities, K-12 schools, local government and hospitals.

Two of the many opportunities for promoting such partnerships are described here – the Energy Efficiency Loan Program and opportunities for increased energy efficiency in publicly funded hospitals.

Energy Efficiency Loans for K-12 Schools and Local Governments

Background

Missouri's energy-efficiency loan program, administered by the Energy Center, makes funds available to any energy-consuming facility or building owned and operated by a local government or school district. The loan program was established for K-12 schools in 1989 and for local governments in 1990. More than 100 government loan recipients and 153 Missouri school districts have invested in energy efficiency since the program has been in operation at an average project payback of 3.7 years. The loans are repaid from savings generated by energy-efficient capital improvement projects.

To qualify, school and local government projects must be capable of paying back the loan in ten years or less or 80 percent of the useful life of the measure. School loans are repaid based on payback at a fixed interest rate below market rate.

Most projects improve the efficiency of space heating by installing ground source heat pumps, temperature control systems and more efficient boilers. Lighting projects have included replacements of ball field, street and exit lights.

Projects can also involve replacing the use of fossil fuels with renewable energy. For example, a project at Pattonville R-III School District to convert its natural gas boilers to burn waste

methane gas from a nearby landfill exceeded its projected cost savings and paid for itself in less than a year.

Estimated fuel savings and avoided emissions from Energy Efficiency Revolving Loans for the past four years of the program are as follows:

Fiscal Year	Approved Loan Amount	Carbon Dioxide (lbs./year)	Nitrogen Oxides (lbs./year)	Sulfur Dioxide (lbs./year)
1997	\$926,854	5,544,165	14,063	30,579
1998	\$1,861,568	10,366,458	35,801	77,847
1999	\$8,953,115	41,558,042	161,061	350,213
2000	\$4,755,678	21,974,576	81,619	177,474
Total	\$16,497,215	79,443,241	292,544	636,113

As illustrated by these estimates, there is a consistent relationship between loan amounts and energy and emissions savings. The state could increase these savings by lending more money to qualified projects. However, this would require finding ways to increase the amount of capital available.

Action Options

Action options to enhance the impact of the Energy Efficiency Loan Program include the following:

- The state should develop a new source of capital in order to provide additional school and local government energy-efficiency loans. This would increase the emissions reductions and other public benefits achieved by the loan program, as project data indicates that there is a consistent relationship between money lent and benefits achieved. The new source of funding should be long-term and should be consistent with the self-sustaining nature of the loan fund. One possible new source of capital that is being explored is the leveraging of private sector funds through a bond issue.
- In conjunction with its energy-efficiency loan program, the state could distribute information about the purposes and resources offered by the ENERGY STAR program for schools and governments
- As recommended by MSES, lighting demonstration centers and displays should be developed around the state. The state of Missouri could take the initiative in developing partnerships with ENERGY STAR, lighting companies, utilities, schools and local governments to place efficient lighting and lighting displays in Missouri's school and local government buildings. Funding for this initiative should be separate from the energy-efficiency loan fund.

Hospitals

Background

A total of 152 licensed hospitals operate in the state of Missouri. Hospitals are energy-intensive operations. As a rule of thumb, variable energy costs in hospitals run an average \$2.12 per square foot, and efficiency upgrades can typically yield as much as 30 percent energy savings. (Clark Reed, U.S. EPA) While data on total square feet of building space is not available, it is clear that hospital buildings represent a significant opportunity to achieve energy efficiency and reduce operating costs.

As with other buildings, a major portion of hospital energy use is electricity use. Hospital end uses of electricity are distributed on average as follows: lighting 44 percent, office equipment 17 percent, ventilation 8 percent, air conditioning 10 percent, refrigeration 5 percent, and miscellaneous equipment 13 percent.

The ENERGY STAR program has recommended that efforts to upgrade hospital energy use begin with lighting upgrades. Lighting upgrades directly reduce the largest portion of the hospital's electricity bill and also reduce the burden that waste heat imposes on ventilation and air conditioning.

However, hospitals afford multiple opportunities for energy improvements that are best achieved through an integrated, step-by-step whole-building approach such as that recommended by the ENERGY STAR for Healthcare program.

The variety of energy and cost savings opportunities is illustrated by an improvement program recently undertaken at Bellin Hospital in Green Bay, Wisconsin. The facility recently began implementing improvements that will save about \$21,000 annually through a state government-industry partnership called "Wisconsin Focus on Energy." The state provided technical resources, and the hospital agreed to initiate management measures and install equipment to improve energy efficiency. Equipment upgrades generally followed ENERGY STAR guidelines. The changes being implemented at Bellin include upgrades of lighting, kitchen equipment and space heating. Two specific examples include energy efficient pumps to regulate hot water flow that will save \$1,500 per year and occupancy sensors to control air flow that will save \$5,800 in HVAC costs.

In general, hospital facility managers are aware of or quickly recognize the potential for energy savings in their facilities. One goal of state action should be to fortify the ability of facility managers to bring energy-saving opportunities to the attention of the CEO and CFO of their organizations and demonstrate their value in the face of competing investment opportunities.

Action Options

- The state could partner with the Missouri Hospital Association, its association of hospital facility managers, the Rolla Industrial Assessment Center, the ENERGY STAR program and other stakeholders to assess and pursue opportunities for cost-effective energy efficiency and conservation measures in Missouri hospitals. Missouri hospitals are major institutional

energy consumers and have many ties with Missouri state government and other public bodies. In the 1980s, under the Institutional Conservation Program, Missouri hospitals were recipients of large state energy conservation loans. This lending program was discontinued, and there is no source of capital to resurrect it. Unless a major new source of funding is developed, the proposed initiative would rely on existing resources and would focus primarily on the deployment of information and removal of institutional barriers. The initial assessment by the partners might indicate opportunities in which a relatively small financial incentive could swing hospital investment decisions toward energy efficiency. Funds for such a purpose could come from a variety of sources such as energy-efficiency monies in a public benefits fund as described below.

- As with schools and local governments, hospitals might be invited to participate in a statewide initiative to develop lighting demonstration centers and displays that could be placed in hospital buildings. The ENERGY STAR program has identified lighting improvements as a logical first step in a five-step program to improve energy efficiency in hospital buildings.
- The state could include as a partner the University of Missouri-Rolla University Outreach and Extension (UMR-UOE), which is developing a new project to identify and evaluate opportunities for energy efficiency and operation enhancement in Missouri hospitals. Based on its past experience with industrial assessment programs sponsored by U.S. DOE, the UMR-UOE has developed a four-stage plan. The first stage involves conducting an on-site assessment in which a UMR team inventories the hospital's use of lighting, motors, air compressors and boilers, provides a summary of the hospital's energy usage and provides Assessment Recommendations together with the expected cost and energy savings. Following the on-site assessment, the program presents a seminar on "Energy Efficiency and Management" illustrating how to estimate and calculate all figures and provides a hands-on training and walk-through in which hospital staff recreate everything the UMR-UOE did for the first step. This assists the hospital client in the development of assessment skills and provides interactive support, as the UMR-UOE team would be present to answer questions and clarify concepts. The fourth step is a local health fair/Building Energy Checkup Seminar at a later date. A similar four-stage program is planned for community buildings.

Voluntary Programs and Partnerships - Residential Buildings

The state has a number of action options to promote energy efficiency and renewable energy in Missouri's residential sector by building on previous experience, existing programs and available resources and opportunities. These include...

Low-Income Weatherization

Background

The Missouri Department of Natural Resources' Energy Center has administered a Low-Income Weatherization Program (LIWAP) since 1977. The program aims to lower utility bills and improve comfort in low-income Missouri residences while ensuring health and safety. Assistance consists of a home audit, installation and a quality-control inspection. Installations, which are

subject to U.S. DOE weatherization guidelines, have focused on assuring a safe and efficient building shell and space heating system.

Lasting energy-efficient improvements are installed in the home, resulting in lower utility bills year after year. A home that has been weatherized can reduce average annual fuel costs per dwelling by up to 13.5 percent, with electricity at 12.2 percent and natural gas at 23.4 percent, making it a cost-effective means to help low-income families with their energy bills. The average energy budget savings are approximately \$220 per household (1990 dollars). This reduces the amount of assistance needed to pay higher utility bills in low-income households.

The Energy Center administers federal funds and state oil-overcharge appropriations to eighteen agencies – 16 regional community action agencies, a city government and a not-for-profit organization – that provide weatherization services, training and guidance to eligible clients.

These agencies also draw on additional “leveraged” funding sources, such as the Missouri Housing Trust, the Springfield Board of Realtors, utilities, corporations and landlords, to provide weatherization services to additional low-income homes.

In FY2000 (July '99 to June '00), about 2100 homes were weatherized through the Energy Center's LIWAP program, resulting in estimated energy savings of about 56 billion Btu. Last year, an additional 780 homes were weatherized, using about \$1.25 million of leveraged funds. A stipulation in the settlement of a recent natural gas tariff case will increase total leveraged funds by an annual contribution of \$125 thousand from Ameren, the state's largest utility.

Action Options

As recommended by the EFC, the state should support the development and coordination of state resources to assist low-income families in making their homes more energy efficient. This includes the maintenance and expansion of the existing Low-Income Weatherization Program.

- U.S. DOE or Missouri could dedicate more funding or new funding sources to the weatherization program. Current funding sources for the Energy Center's weatherization program are DOE weatherization funds and Utilicare funds from state General Revenue.
- In accordance with a recommendation in the Missouri Statewide Energy Study, the maximum allowable Low-Income Home Energy Assistance Program (LIHEAP) funds should be dedicated to weatherization. Federal LIHEAP funds were also used for weatherization in the past, but the state has not released LIHEAP funds for this purpose in recent years.
- Given additional funding, Missouri's weatherization program could readily be expanded to weatherize more homes. While the number of homes weatherized in 2000 is substantial, the program weatherized three times as many homes in 1987. The decrease in activity is due to a reduction in federal funds, not a lack of candidates for weatherization. It has been estimated that at the current rate of weatherization, it would take about 90 years to weatherize all low-income homes that are eligible and would benefit from weatherization.
- In addition to weatherizing more homes, the state, the weatherization agencies or a leveraged fund provider could consider extending the scope of the weatherization program to increase

both the economic and GHG benefits of weatherization. For example, a limited pilot program could be put in place to explore the expansion of weatherization services to include the following:

- Electric baseload appliances such as refrigerator replacement or air conditioning: The program could test the concept of providing a “cool room,” rather than providing air conditioning for the entire residence.
- Cost-effective renewable technologies: A possible model is the several Pennsylvania utility-based pilot renewable projects to install solar hot water heaters in low-income residences. Because the solar hot water installations in these projects were estimated to cost \$3000 each, a supplementary source of financing would be required.

Federal ENERGY STAR Labeling Program

Background

The U.S. EPA introduced ENERGY STAR in 1992 as a voluntary labeling program designed to identify and promote energy-efficient products in order to reduce carbon dioxide emissions. U.S. EPA partnered with the U.S. DOE in 1996 to promote the ENERGY STAR label, with each agency taking responsibility for particular product categories. The labeling program has expanded to cover new homes, most buildings and a wide variety of residential and commercial equipment. The program has continued to expand, with plans to cover new items such as electric motors, ceiling and ventilation fans, reach-in refrigerators and vending machines, and light commercial HVAC and telephony.

The ENERGY STAR label covers equipment for most of the important residential energy end uses, such as residential space heating and cooling equipment, clothes washers, dishwashers, refrigerators and air conditioners. The label also includes items in the fast-growing “miscellaneous” segment of residential electricity such as consumer electronics and computer equipment. The lighting standard applies only to compact fluorescent lighting. Water heaters are not included.

Appliances carrying the label must provide a defined level of efficiency that is higher than federal minimum standards. As federal standards increase or new technologies are commercialized, the requirements for the ENERGY STAR label also increase. Current ENERGY STAR specifications for appliances can be found at the ENERGY STAR Web site (www.energystar.gov).

A consumer who simply wants an easy way to identify energy-efficient equipment for purchase can rely on the label to translate technical detail into easily understood comparisons. Federal appliance standards are based on a variety of technically defined measures such as EER or SEER (Seasonal Energy Efficiency Rating) for air conditioners and heat pumps or EF and MEF (Modified Energy Factor) for clothes and dishwashers. The consumer who relies on the ENERGY STAR label does not need to understand the technical basis for these measures to know that an ENERGY STAR labeled clothes washer is at least 50 percent more efficient than the minimum federal standard or that an ENERGY STAR labeled dishwasher is at least 25 percent more efficient than the minimum federal standard.

While it is primarily a labeling program, ENERGY STAR also provides information resources for residential consumers with various levels of informational needs. The residential consumer who wants to dig deeply into the energy use, cost and energy impact of equipment decisions can use the ENERGY STAR program's published and online resources to do so.

Action Options

The state should support and promote the ENERGY STAR labeling program as a means to promote more rapid incorporation of energy-efficient technologies and to provide the basis for a long-term program of consumer information on available residential energy-efficiency options.

Reviewing state options to reduce GHG emissions from the building sector, STAPPA/ALAPCO concludes that voluntary labeling programs offer the greatest promise to achieve GHG emission reductions. Support and promotion of the ENERGY STAR label offers a cost-effective opportunity for the state of Missouri to pursue this strategy on a long-term basis in partnership with the federal government and Missouri utilities.

The MSES, which was published before the ENERGY STAR program was initiated, recommends that Missouri join with other states to require all appliances sold to have a label that includes data such as energy use comparison, life cycle costs and payback on more efficient models. Because most manufacturers serve national markets, it is more effective and efficient to develop labeling programs at a national level. Implementing the labeling program recommended by MSES at a state or even regional level would be expensive and fraught with practical, technical and political obstacles. By building marketing and technical information programs around the federally developed ENERGY STAR label, Missouri could achieve most of the objectives of the MSES recommendation while avoiding its costs.

As the following table indicates, most residential appliances have a useful life of 15 years or more. Therefore, an upgrade program has to cover many different kinds of equipment and extend over a long time period to optionally capture cost-effective opportunities for energy efficiency. The ENERGY STAR program covers a wide and ever-increasing range of energy-efficiency equipment and enjoys the federal government's long-term commitment.

Equipment	Minimum Life	Maximum Life
Heat Pumps	8	16
Central Forced-Air Furnaces	18	29
Hydronic Space Heaters	20	30
Room Air Conditioners	12	19
Central Air Conditioners	8	16
Water Heaters	12	19
Cooking Stoves	16	21
Clothes Dryers	6	30
Refrigerators	7	26
Freezers	11	31

Source: EIA *Annual Energy Outlook 2001* documentation, based on Lawrence Berkeley Laboratory, *Baseline Data for the Residential Sector and Development of a Residential Forecasting Database*, May 1994, and analysis of RECS 1997 data.

The federal government's long-term commitment of technical and financial resources to the ENERGY STAR label provides a unique opportunity for Missouri. Adopting the ENERGY STAR label as a reference point for its own education and incentive programs appears to be a cost-effective way for Missouri to stretch its own technical information and marketing resources and establish and maintain a long-term, comprehensive energy information program.

Home Energy Ratings Systems (HERS)

Background

A Home Energy Rating System (HERS) is essentially an energy-efficiency labeling program for residential buildings that is targeted at reducing market barriers that prevent optimal investment in residential shell and HVAC efficiency. A successful HERS program increases the valuation of energy-efficient homes on the marketplace and also facilitates the willingness of lenders to take shell and HVAC improvements into account when making mortgage loan decisions.

Lenders traditionally do not credit efficiency improvements when determining mortgage interest rates or amounts, even though efficiency investments reduce lender risk by increasing the borrower's monthly cash flow. A Home Energy Rating System is intended to overcome this barrier by institutionalizing energy ratings that allow participating lenders to take home efficiency improvements into account in decisions on the amount or terms of mortgage loans.

The 1992 Missouri Statewide Energy Study and the 1993 House Concurrent Resolution 16 recommended HERS as a strategic priority to change energy consumption patterns for Missouri's

residential sector. Since that time, the Energy Center and other state agencies have sponsored and participated in a variety of stakeholder and informational meetings and have explored several mechanisms for state support of HERS. The state should continue to provide reliable, timely information to consumers, builders, lending institutions and other stakeholders concerning the benefits and implementation of HERS.

HERS relies on Home Energy Ratings to indicate the energy efficiency of a new or existing house. Computer software is used to model a home's energy usage and compare the home's energy performance against the best performance possible for that structure.

A Home Energy Rating will help a home buyer to identify energy-efficient homes for purchase and understand the energy costs associated with their most valuable asset – their home. A rating will indicate cost-effective investments in energy-efficiency improvements such that the reduction in ongoing energy costs outweighs the up-front cost of improvement.

An energy-efficient mortgage credits a home's energy efficiency in the home loan, allowing the borrower a greater debt-to-income ratio and giving the home buyer the ability to buy a higher-quality home because of the lower monthly costs of heating and cooling the home. Alternatively, an energy improvement mortgage finances cost-effective improvements recommended in an energy rating at the time of sale or refinancing. Funds are placed in escrow until the improvements are made, then released to pay for materials and contracted labor.

Energy mortgages are sponsored by federally insured mortgages programs [Federal Housing Administration (FHA) and Veterans Administration (VA)] and the conventional secondary mortgage market (Fannie Mae and Freddie Mac).

In the United States, HERS systems generally have had problems going mainstream. Fewer than 2 percent of new homes receive an energy rating, according to industry sources, and most are utility programs with rate-payer subsidies. (ASE) Lenders are often unaware of energy-efficient mortgage programs available through Fannie Mae, Freddie Mac, FHA and VA. Builders are frequently reticent to engage in any program that can delay their construction schedules, add costs for ratings or that require significant changes in building practices.

Action Options

- As recommended by the EFC, the state should support the development and implementation of HERS. Home-energy raters operating in Missouri, including staff from a number of community action agencies, have been trained and certified by either of two accredited HERS Providers – the Kansas Building Science Institute (KBSI) based in Manhattan, Kansas, or the Energy Rated Homes of America (ERHA) based in North Little Rock, Arkansas. Both KBSI and ERHA are recognized by FHA, VA, Freddie Mae and Freddie Mac. The state should continue to recognize both providers and assist consumers with provider-neutral, fact-based data that will help them make their own decisions.
- In addition to promoting consumer awareness of HERS, the state could also sponsor information resources and seminars specifically targeted to lenders. State agencies such as the Missouri Housing Development Corporation that deal with home mortgages as a normal part of daily business are particularly well-positioned to promote lending industry awareness

and knowledge of HERS and to facilitate stakeholder meetings focused on overcoming barriers to the program's success.

Incentive Programs

Manufacturers, the federal government, state governments and utilities have tried nearly every conceivable combination of education and incentives to encourage consumers to voluntarily adopt new and more energy-efficient technologies. The following sections discuss the state's two options for assuring that incentive programs are available to Missouri residential consumers – requiring utilities to provide DSM programs and creating state incentive programs.

A recent Pew Center study, *Appliances and Global Climate Change*, categorizes incentive programs into three categories: equipment upgrade programs, early-replacement programs and retirement programs. The report provides extensive analysis of the target group for each type of program and the program design requirements. All three types of programs can achieve cost-effective GHG reductions, but upgrade programs are easiest to implement, require the least intervention in normal end user behavior and probably have the greatest potential to achieve results per program dollars spent.

Because both early-replacement and appliance retirement programs attempt to convince the end user to give up equipment that still has a useful life, they must offer a substantial financial incentive, usually in the form of a rebate, in order to succeed. Upgrade programs, on the other hand, target end users of equipment that has reached the end of its useful life. The purpose of an upgrade program is to persuade the user to invest in energy efficiency. Given that the investment in energy efficiency will save money over the life cycle of the investment, an upgrade program does not necessarily have to offer large financial incentives to succeed, but it must be designed effectively to reach the correct end users and deliver persuasive point-of-sale information. The Pew Center study offers guidelines on how programs may be designed to accomplish this.

A state-run program can offer several different types of financial incentives – for example, rebates, loans and tax credits. A fundamental distinction is between initial-cost and annual-cost incentive programs.

Initial-cost incentive programs are designed to reduce the initial cost of adopting energy-efficient technology. Rebates, tax credits and in-kind services such as audits are all initial-cost incentives.

Rebates have been standard instruments used by innumerable utility, government and manufacturer incentive programs. Several Missouri state incentive programs have offered audits, but the state has sponsored only one rebate program, for chipper stove (renewable energy) in the mid-80s.

Standard rebate programs were attractive to utilities in the early- to mid-90s because they were relatively easy to design and implement. However, standard rebate programs rarely lead to long-term changes in consumer behavior or in the market place. By the late '90s, many utilities had dissolved standard rebate programs in favor of adopting national programs such as ENERGY STAR homes and ENERGY STAR buildings, which permitted them to reduce costs, commit to a long-term effort and focus on providing technical services.

In recent years, government rebate programs have also become less common and are usually cast within the framework of a market transformation initiative. Both the Northwest Energy Efficiency Alliance and Northeast Energy Efficiency Partnership have recently initiated closely studied rebate-based market transformation campaigns to promote adoption of energy-efficient technologies such as motors, compact fluorescent lights and clothes washers.²

Tax credits are an increasingly popular instrument for federal and state incentive programs, in part because of the perceived difficulty of administering a rebate program.

There is evidence to indicate that tax credits may not be as attractive to residential consumers as rebates, in part because tax credits are deferred and rebates are received immediately. However, a government-run tax credit program might provide the tax credits to vendors and allow them to use the credits to pay for consumer or dealer rebates. Moreover, some tax devices, such as sales tax exemptions, may be more attractive than deferred tax credits. For example, Maryland offers a sales tax exemption for purchases of ENERGY STAR qualified air conditioners, water heaters, clothes washers, refrigerators and central heating and cooling equipment as well as solar water heating and photovoltaic equipment. The Maryland tax credit was implemented too recently to assess its results.

Annual-cost incentive programs are designed to reduce (or level) the annual costs of adopting energy efficient technology. State-run programs of this type rely on low-interest loans. Utility programs can offer a wider range of incentives, including low-interest loans and leasing and/or inclusion on the utility bill.

Historically, most of Missouri's experience with state incentive programs has relied on low-cost loans. The Energy Center, which now offers energy-efficiency loans to schools and local governments, also offered low-interest loans in the 1980s to residential consumers for energy efficient appliances and building shell improvements. The residential loan program ended when oil overcharge funds for it became unavailable.

The Pew Center study's review of past lending programs indicates that loans, like tax credits, may not be as attractive to consumers as rebates. However, Nebraska's Dollar & Energy Savings Loan program offers an example of a state-run low-interest loan program that has successfully promoted residential energy efficiency.

Run by the Nebraska Energy Office (NEO), the program permits residential as well as commercial end users to receive low-interest financing for energy-efficient equipment covering a full range of technologies including space heating and air conditioning, water heating, appliances, lighting, windows, doors, shell improvements and many other end uses. Any equipment can qualify for a loan if it meets specific energy-efficiency standards. The consumer arranges the loan through a local bank, and the Energy Office then purchases 50 percent of each loan from the bank at zero percent interest. This doubles the lender's effective interest rate. If the institution is willing to make the loan, NEO is willing to purchase half of the loan.

² Biewald, Bruce, David White, and Tim Woolf, Synapse Energy Economics, Inc., and Frank Ackerman and William Moomaw, Global Development and Environment Institute, *Grandfathering and Environmental Comparability: an Economic Analysis of Air Emission Regulations and Electricity Market Distortions*, National Association of Regulatory Utility Commissioners, June 11, 1998.

Total loans to date equal about \$100 million, of which about 70 percent have been for residential energy efficiency. The program has been widely used in rural areas but has also been popular in metropolitan areas, including low-income neighborhoods. Average loan size has been about \$5,000, and the default rate has been very low at about .06 percent. State administrative costs are low because the loan administration is handled by the banks.

While the success of Nebraska's program is encouraging, a loan fund based on the Nebraska model would require a substantial funding commitment in order to succeed. Because low-interest loans are available for a full range of technologies, and the amount to be lent is determined by bank lending decisions, the state loses control over how much money is lent. Twice in its history, the program has run out of loan funds and has been bailed it out with additional oil overcharge reserves. If additional funds had not been available, or if the state had limited the range of technologies available for loans, it is likely that the program would have lost its credibility with borrowers and banks.

Utility Support for Demand-Side Management (DSM)

Background

Demand-Side Management (DSM) consists of electric utilities' planning, implementing and monitoring activities designed to encourage consumers to modify their levels and patterns of electricity consumption. These activities are performed to benefit utilities, consumers and society.

Utilities implement DSM programs to achieve two basic objectives: energy efficiency and load management. Energy efficiency is primarily achieved through programs that reduce overall energy consumption of specific end-use devices and systems by promoting high-efficiency equipment and building design. Energy-efficiency programs typically reduce energy consumption over many hours during the year.

Load-management programs, on the other hand, are designed to achieve load reductions and are primarily implemented at the time of peak load. In Missouri, peak requirements are highest during the summer due to widespread use of air conditioning. Load-reduction programs generally have little effect on total energy consumption and therefore little effect on GHG emissions. They may affect NOx and other emissions, however, if plants used to provide peak power have higher emissions rates than baseload plants.

Nationally, the level of utility commitment peaked in 1996 and has declined as utilities pulled back from DSM programs in anticipation of new, deregulated markets. This decline in DSM programs occurred even as utilities were becoming more sophisticated in their implementation of DSM programs and the programs themselves were becoming more effective achieving in their intended results.

Missouri trends have followed national trends. The Integrated Resource Planning (IRP) process established by PSC rule in 1994 requires utilities to consider DSM as an alternative resource for bringing generation into balance with demand. The public interest rationale for IRP is sound and well-established. However, as described in the chapter on electricity generation options, Integrated Resource Planning has not been required in Missouri since 1995.

Data collected by EIA from U.S. utilities indicates that in general, Missouri utility support for energy-efficiency DSM has not been as strong as the U.S. utility average. For example, in 1996, the energy savings from DSM programs conducted by U.S. utilities reduced total power use by approximately 2 percent of the annual electricity sales of these utilities to ultimate consumers. (EIA, Electric Utility Demand Side Management 1996, p. 3) The ratio of Missouri utility DSM energy savings to electricity sales has consistently remained well below 1 percent.

Action Options

- The PSC could require Missouri utilities to implement a target level of energy-efficiency demand-side management (EE-DSM) programs in their service area based on percentage of total sales in their service territory. The target levels could be tagged to the U.S. utility average. For example, the target could be based on U.S. utility average rate of expenditures per sales or average rate of achieved energy savings from DSM programs per sales. The target would set a framework for the utility's DSM effort, but otherwise, the utility would determine the design of the DSM programs. The state could offer to provide technical support by arranging conferences, symposia and consultation on cutting-edge EE-DSM program design. This option assumes continued regulation of electric utilities.
- Alternatively, utilities could be given the option to provide funding, based on level of in-state electricity sales, for a statewide DSM or market transformation program. It is uncertain whether this would be a viable option under deregulation.
- As described in the chapter on electric generation options, Missouri could implement a public benefits fund in lieu of requiring utility funding for DSM. Following the example of a number of other states, Missouri could base funding on a non-bypassable wire charge on all electricity sales and could devote a portion of the fund to initiatives promoting adoption of energy efficiency in Missouri buildings. This option could be implemented regardless of whether Missouri's electric utility industry is deregulated.

State-Sponsored Incentive Programs for Residential Energy Efficiency

Background

The introduction to the policy section of this chapter introduced the concept of market transformation initiatives. A marked change in state actions to provide incentives for residential adoption of energy efficiency is that increasingly, they are designed with market transformation as an objective.

Massachusetts provides an example of a state market transformation program. In 1997, Massachusetts established a public benefits fund based on a non-bypassable wire charge, part of which is dedicated to promoting energy efficiency and renewables in the state's buildings. The program is run by Massachusetts' state energy office, which has issued its first annual report on program results. As would be expected, the report emphasizes statistics on immediate dollar and energy benefits that accrued to Massachusetts' citizens. For example, the efficiency investments made would result, over their lifetime, in total savings of \$265 million and a reduction of about 2 million tons of CO₂, 1,335 tons of SO₂ and 1,795 tons of NO_x. However, the report also discusses the program's long-term market transformation objectives, concluding that

Such market transformation efforts [which] mainly seek to change the fundamental behavior of market players...capture opportunities for more widespread and in the long term, more cost-effective energy efficiency than other types of programs. (MDOE, p. 5)

A U.S. EPA review of market transformation programs indicates that they can “play a very effective third-party role in promoting energy-efficient products to consumers in local markets.” In 1999, states with MT programs achieved an ENERGY STAR market penetration of 11.76 percent, while the total national average was 8.53 percent, and the average for states without MT programs was 7.24 percent.

Specific market transformation initiatives require careful design based on identification of unique market opportunities, clear specification of the target consumers and careful analysis of the cost effectiveness of the technology to be promoted. Because that level of analysis is not possible or appropriate in this report, only general options and recommendations are presented here.

Action Options

- Funding sources and incentive types the state may wish to consider:
 - Find new funding sources for initiatives to promote support of energy-efficient and renewable building technologies by residential consumers and other market players.
 - Create a public benefits fund partially dedicated to promoting energy efficiency and renewable energy in buildings.
 - Explore the full range of possible types of financial incentives – low-interest loans, rebates, in-kind services and tax credits – and select incentives specifically tailored to technology, end use and the type of customer decision that is to be affected.
- Program design
 - Future state initiatives meant to provide incentives to residential consumers for adopting energy-efficient technologies should be conceived and structured as market transformation initiatives.
 - Initiatives should be targeted to specific technologies. Ideally, the technology should offer favorable life cycle and payback economies and significant impact on CO₂ and other energy-related emissions.
 - Initiatives should be designed to take advantage of opportunities for partnership, including with regional partners such as MEEA.
 - Initiatives should be designed as either upgrade, early-replacement or appliance retirement programs because the three types have different design requirements. In general, upgrade programs should be emphasized because they provide the greatest long-term cost effectiveness.
 - Initiatives focused on upgrades of technologies with long life cycles should be designed as long-term programs.

- When designing a market transformation initiative, if there is an ENERGY STAR performance level for the particular technology, the state should adopt that standard into the initiative unless there is a specific reason not to do so and should seek partners in promoting the ENERGY STAR label.
- Possible target end uses and technologies
 - The following discussion targets three end uses that, according to the 5-lab analysis, offer large potential residential energy and carbon savings in absolute terms (total tons reduced) and percentage terms (potential energy and carbon savings per unit). The three end uses, also emphasized in the technology options section, are lighting, space cooling and water heating.
 - The state could implement an ENERGY STAR lighting initiative after the example of Wisconsin's Focus on Energy initiative. An initiative focused on a lighting program and the ENERGY STAR label would be well suited for a partnership with utilities in the state.
 - The state could implement an initiative focused on educating the public about the new federal room air conditioner standards, the benefits of proper sizing and management of room air conditioners and point-of-sale promotion and incentives for ENERGY STAR labeled air conditioners. This initiative would be well suited for partnership with major vendors and retailers in the state.
 - The state could implement a residential solar water heating initiative, promoting the use of renewable energy to directly displace electricity use. Solar water heating is further discussed in the chapter on Electric Generation.

Table 9: Residential CO₂ Emissions - Projected “Business-as-Usual” Emissions and Impact of Achieving 5-Lab “Technoeconomic Potential” for Reductions

1. CO2 emissions (thousand tons) from electric generation in response to residential demand for electricity											
	1990	1998	1999	2010				2020			
				<i>Business as usual</i>	<i>Growth rate (1990-2010)</i>	<i>Potential to reduce</i>	<i>Potential reductions</i>	<i>Business as usual</i>	<i>Growth rate (1990-2020)</i>	<i>Potential to reduce</i>	<i>Potential reductions</i>
Space Heating	2,083	2,670	2,567	3,146	2.1%	8%	252	3,465	1.7%	17%	589
Space Cooling	3,165	4,057	3,506	4,235	1.5%	18%	762	5,205	1.7%	27%	1,405
Water Heating	2,230	2,858	2,663	2,907	1.4%	27%	785	2,926	0.9%	30%	878
Refrigeration	2,485	3,185	2,885	2,315	-0.3%	15%	347	2,197	-0.4%	31%	681
Cooking	577	739	691	806	1.7%	12%	97	894	1.5%	11%	98
Clothes Dryers	1,207	1,547	1,460	1,749	1.9%	27%	472	1,959	1.6%	20%	392
Freezers	695	891	796	601	-0.7%	11%	66	592	-0.5%	21%	124
Lighting	1,871	2,398	2,294	3,118	2.6%	60%	1,871	3,505	2.1%	64%	2,226
Clothes Washers	167	213	199	233	1.7%	36%	84	259	1.5%	50%	130
Dishwashers	120	154	143	163	1.5%	0%	-	186	1.5%	0%	-
Color Televisions	650	833	818	1,281	3.5%	21%	269	1,613	3.1%	25%	403
Pers. Computers	62	385	433	634	12.3%	0%	-	773	8.8%	0%	-
Furnace Fans	415	532	504	657	2.3%	44%	289	781	2.1%	75%	586
Other Uses	4,967	7,352	7,459	11,704	4.4%	41%	4,760	14,869	3.7%	48%	7,187
Total Electricity	20,694	27,815	26,418	33,548	2.5%	28%	9,393	39,224	2.2%	37%	14,513
2. CO2 emissions (thousand tons) from residential combustion of natural gas											
	1990	1998	1999	2010				2020			
				<i>Business as usual</i>	<i>Growth rate (1990-2010)</i>	<i>Potential to reduce</i>	<i>Potential reductions</i>	<i>Business as usual</i>	<i>Growth rate (1990-2020)</i>	<i>Potential to reduce</i>	<i>Potential reductions</i>
Space Heating	4,461	4,216	4,329	5,181	0.8%	5%	259	5,796	0.9%	12%	695
Space Cooling	0	0	0	3	12.3%	0%	-	5	10.0%	0%	-
Water Heating	1,828	1,727	1,697	1,898	0.2%	13%	247	2,047	0.4%	17%	348
Cooking	272	257	252	303	0.5%	Note 1	Note 1	342	0.8%	10%	34
Clothes Dryers	95	89	89	121	1.2%	Note 1	Note 1	147	1.5%	Note 1	Note 1
Other Uses	166	157	153	152	-0.4%	9%	14	145	-0.4%	10%	15
Total natural gas	6,822	6,447	6,521	7,659	0.6%	5%	383	8,481	0.7%	12%	1,018

Note 1: The 5-Lab scenario includes fuel switching from electricity to natural gas resulting in increased natural gas use for cooking and clothes drying in 2010 and for clothes drying in 2020. This is reflected in the “delivered energy” total.

Table 10: Commercial CO₂ Emissions - Projected “Business-as-Usual” Emissions and Impact of Achieving 5-Lab “Technoeconomic Potential” for Reductions

1. CO2 emissions (thousand tons) from electric generation in response to commercial demand for electricity											
	1990	1998	1999	2010				2020			
				<i>Business as usual</i>	<i>Growth rate (1990-2010)</i>	<i>Potential to reduce</i>	<i>Potential reductions</i>	<i>Business as usual</i>	<i>Growth rate (1990-2020)</i>	<i>Potential to reduce</i>	<i>Potential reductions</i>
Space Heating	759	907	909	1,055	1.8%	20%	211	1,033	1.1%	39%	403
Space Cooling	2,570	3,069	2,748	2,949	0.8%	29%	855	2,982	0.6%	48%	1,431
Water Heating	805	961	935	1,031	1.3%	16%	165	1,014	0.8%	11%	112
Ventilation	879	1,149	1,122	1,325	2.2%	26%	344	1,356	1.5%	45%	610
Cooking	161	211	204	200	1.2%	0%	-	183	0.5%	0%	-
Lighting	6,688	7,987	7,815	9,202	1.7%	20%	1,840	9,520	1.2%	24%	2,285
Refrigeration	924	1,209	1,181	1,380	2.1%	22%	304	1,451	1.6%	38%	551
Office Equip. (PC)	244	628	674	1,537	9.8%	0%	-	1,900	7.2%	0%	-
Off. Equip.(non-PC)	844	1,874	1,909	3,290	7.1%	0%	-	4,457	5.8%	0%	-
Other Uses	4,875	6,528	6,374	9,588	3.5%	24%	2,276	12,329	3.2%	33%	4,027
Total Electricity	18,749	24,523	23,870	31,558	2.7%	19%	5,996	36,225	2.3%	26%	9,419
2. CO2 emissions (thousand tons) from commercial combustion of natural gas											
	1990	1998	1999	2010				2020			
				<i>Business as usual</i>	<i>Growth rate (1990-2010)</i>	<i>Potential to reduce</i>	<i>Potential reductions</i>	<i>Business as usual</i>	<i>Growth rate (1990-2020)</i>	<i>Potential to reduce</i>	<i>Potential reductions</i>
Space Heating	1,513	1,556	1,649	2,023	1.5%	27%	546	2,112	1.1%	47%	993
Space Cooling	10	17	18	28	5.0%	38%	11	32	3.8%	38%	12
Water Heating	706	729	748	894	1.2%	13%	116	979	1.1%	15%	147
Cooking	225	233	240	290	1.3%	0%	-	314	1.1%	0%	-
Other Uses	1,039	1,073	1,018	1,289	1.1%	4%	51	1,369	0.9%	7%	98
Total natural gas	3,494	3,608	3,672	4,523	1.3%	16%	724	4,806	1.1%	26%	1,250

Table 12: Projected Increase Through 2010 in Missouri Residential Building CO₂ Emissions (thousand tons) from Electricity & Natural Gas Use Under Business-as-Usual and Three Efficiency Scenarios

	Electricity			Natural Gas			Total		
	<i>Tons of CO₂</i>	<i>Increase from '90</i>	<i>Increase from '99</i>	<i>Tons of CO₂</i>	<i>Increase from '90</i>	<i>Increase from '99</i>	<i>Tons of CO₂</i>	<i>Increase from '90</i>	<i>Increase from '99</i>
1990 Historic	20,694	N/A	N/A	6,822	N/A	N/A	27,516	N/A	N/A
1999 Historic	26,418	28%	N/A	6,521	-4%	N/A	32,939	20%	N/A
Business as Usual	33,548	62%	27%	7,659	12%	17%	41,207	50%	25%
Efficiency Potential	24,155	17%	-9%	7,276	7%	12%	31,430	14%	-5%
Moderate Scenario	30,918	49%	17%	7,578	11%	16%	38,496	40%	17%
Advanced Scenario	30,354	47%	15%	7,551	11%	16%	37,906	38%	15%

Table 13: Projected Increase Through 2020 in Missouri Residential Building CO₂ Emissions (thousand tons) from Electricity and Natural Gas Use Under Business-as-Usual and Three Efficiency Scenarios

	Electricity			Natural Gas			Total		
	<i>Tons of CO₂</i>	<i>Increase from '90</i>	<i>Increase from '99</i>	<i>Tons of CO₂</i>	<i>Increase from '90</i>	<i>Increase from '99</i>	<i>Tons of CO₂</i>	<i>Increase from '90</i>	<i>Increase from '99</i>
1990 Historic	20,694	N/A	N/A	6,822	N/A	N/A	27,516	N/A	N/A
1999 Historic	26,418	28%	N/A	6,521	-4%	N/A	32,939	20%	N/A
Business as Usual	39,224	90%	48%	8,481	24%	30%	47,705	73%	45%
Efficiency Potential	24,711	19%	-6%	7,464	9%	14%	32,175	17%	-2%
Moderate Scenario	32,693	58%	24%	8,257	21%	27%	40,951	49%	24%
Advanced Scenario	29,791	44%	13%	8,115	19%	24%	37,906	38%	15%

Table 15: Projected Increase Through 2010 in Missouri Commercial Building CO₂ Emissions (thousand tons) from Electricity and Natural Gas Use Under Business-as-Usual and Three Efficiency Scenarios

	Electricity			Natural Gas			Total		
	<i>Tons of CO₂</i>	<i>Increase from '90</i>	<i>Increase from '99</i>	<i>Tons of CO₂</i>	<i>Increase from '90</i>	<i>Increase from '99</i>	<i>Tons of CO₂</i>	<i>Increase from '90</i>	<i>Increase from '99</i>
1990 Historic	18,749	N/A	N/A	3,494	N/A	N/A	22,243	N/A	N/A
1999 Historic	23,870	27%	N/A	3,672	5%	N/A	27,542	24%	N/A
Business as Usual	31,558	68%	32%	4,523	29%	23%	36,081	62%	31%
Efficiency Potential	25,562	36%	7%	3,799	9%	3%	29,362	32%	7%
Moderate Scenario	29,340	56%	23%	4,364	25%	19%	33,704	52%	22%
Advanced Scenario	29,040	55%	22%	4,313	23%	17%	33,353	50%	21%

Table 16: Projected Increase Through 2020 in Missouri Commercial Building CO₂ Emissions (thousand tons) from Electricity and Natural Gas Use Under Business-as-Usual and Three Efficiency Scenarios

	Electricity			Natural Gas			Total		
	<i>Tons of CO₂</i>	<i>Increase from '90</i>	<i>Increase from '99</i>	<i>Tons of CO₂</i>	<i>Increase from '90</i>	<i>Increase from '99</i>	<i>Tons of CO₂</i>	<i>Increase from '90</i>	<i>Increase from '99</i>
1990 Historic	18,749	N/A	N/A	3,494	N/A	N/A	22,243	N/A	N/A
1999 Historic	23,870	27%	N/A	3,672	5%	N/A	27,542	24%	N/A
Business as Usual	36,225	93%	52%	4,806	38%	31%	41,031	84%	49%
Efficiency Potential	26,807	43%	12%	3,556	2%	-3%	30,363	37%	10%
Moderate Scenario	31,139	66%	30%	4,494	29%	22%	35,633	60%	29%
Advanced Scenario	30,386	62%	27%	4,306	23%	17%	34,692	56%	26%

Missouri Action Options for Reducing Greenhouse Gas Emissions – July 2002

Chapter 4

Options to Reduce GHG Emissions from the Transportation Sector in Missouri

Chapter 4: Options to Reduce GHG Emissions from the Transportation Sector in Missouri

Background	123
Technical Options to Reduce GHG Emissions from Highway Travel in Missouri	126
Highway Infrastructure and Use	127
Four Areas of Technical Opportunity	129
Vehicle Technology	131
Fuel Economy	131
Alternative Fuel Vehicles	133
Potential Leverage Points for State Influence on Vehicle Technology	138
Vehicle Management	144
Improved Driving Behavior	144
Improved Vehicle Maintenance	145
Public Fleet Management	146
Infrastructure Management and Alternative Modes of Transportation	146
Advanced Highway Management	147
Improved Availability and Attractiveness of Alternatives to Single-Occupant Vehicle (SOV) Trips	151
Alternative Modes for Intercity Travel	152
Alternative Modes for Commuting and Local Travel	153
Promoting Multi-Modal Connectivity of Alternative Transportation Modes	156
Travel Needs and Planning	157
Trip Planning at the Personal Level	158
Transportation Needs Planning at the Institutional Level	159
Telecommuting	159
Teleconferencing	159
Technical Options to Reduce GHG Emissions from Freight Transportation in Missouri	161
Freight Transportation Infrastructure and Use	161
Areas of Technical Opportunity	163
Advanced Highway Freight Technology	164
Advanced Freight Pipelines	164
Intermodal Coordination of Freight Movement	165
Policy Options to Reduce Greenhouse Gas Emissions from Missouri's Transportation Sector	166
Promote the Fuel Efficiency of Highway Vehicles in Missouri.....	168
Promote Alternative and Renewable Fuel Use in Highway Vehicles in Missouri	171

Support Measures that Reduce the Need for Travel and Support a
Variety of Efficient Methods for Travel in Missouri 175

Chapter 4 – Options to Reduce GHG Emissions from the Transportation Sector in Missouri

Background

More than 95 percent of greenhouse gas (GHG) emissions from Missouri's transportation sector are in the form of CO₂ emissions from combustion of petroleum as a transportation fuel. The other significant GHG emitted from the transportation sector, nitrous oxide, also results primarily from combustion of petroleum fuels.

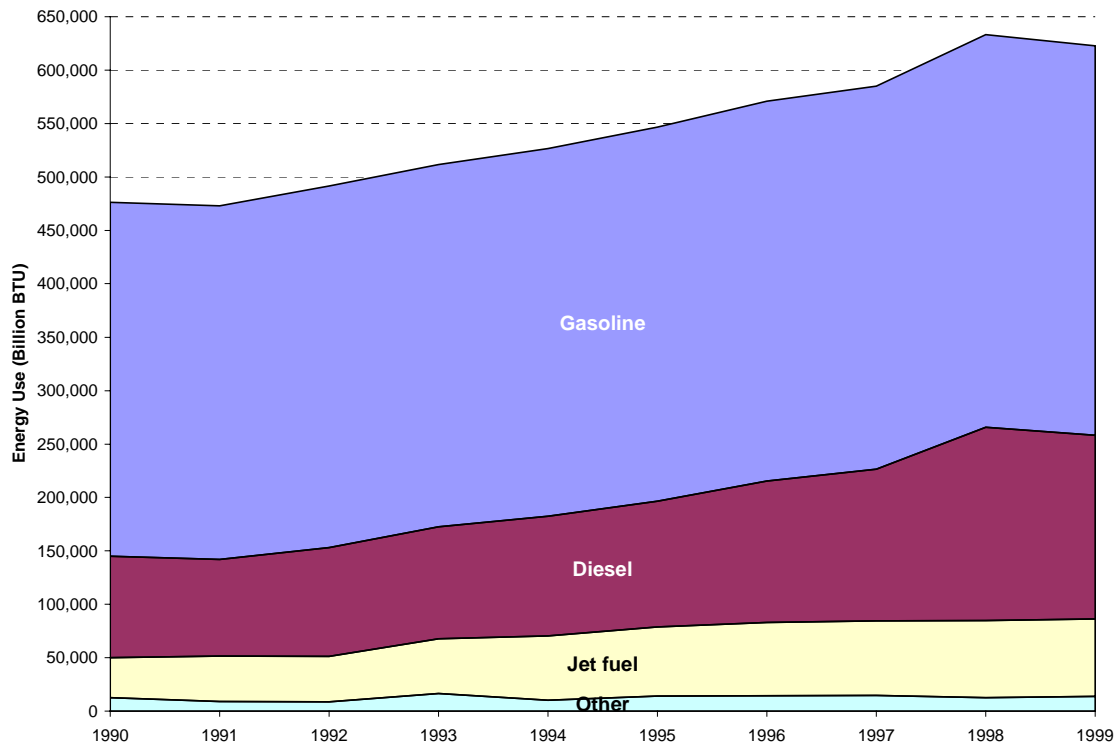
Transportation accounts for about a third of Missouri's total CO₂ emissions from fossil fuel use, second only to the utility sector. This is comparable to the transportation sector's 32 percent share of CO₂ emissions at the national level.¹

The state's transportation sector relies almost exclusively on petroleum-based fuels. In 1999, Missouri derived 98 percent of its transportation energy from three fuels – gasoline (58 percent), diesel (28 percent) and jet fuel (12 percent). These three fuels also accounted for about 98 percent of Missouri's total energy bill of \$4.9 billion.

Chart 1 indicates state consumption of transportation fuels during the 1990s. According to estimates by the U.S. Department of Energy's Energy Information Administration (EIA), state consumption of gasoline, diesel and jet fuel for transportation increased by about 31 percent between 1990-1999, an average annual growth rate of about 3.1 percent.

¹ EIA, *Emissions of Greenhouse Gases in the United States 2000*, Washington, D.C., November 2001

Chart 1: Missouri Consumption of Transportation Fuels, 1990-1999



During this period, expenditures for gasoline, diesel and jet fuel in the transportation sector increased by about 25 percent, an average annual growth rate of about 2.5 percent. Expenditures grew more slowly than consumption because the average price of transportation fuels in Missouri decreased by about 4.5 percent between 1990-1999.²

According to EIA's estimates, the growth of jet and diesel fuel use was particularly rapid. Missouri's consumption of jet fuel in 1999 was 92 percent greater than in 1990, an average annual growth rate of about 7.5 percent. Consumption of diesel fuel use was 81 percent greater, a growth rate of about 6.8 percent. By contrast, gasoline use increased about 10 percent, a 1.1 percent average annual rate of growth.

Because their carbon content is known, CO₂ emissions from use of these three transportation fuels can be estimated based on fuel use.³ According to EIA estimates, CO₂ emissions from the three fuels increased by about a third during the decade, from about 36.3 million short tons carbon dioxide equivalent (STCDE)⁴ in 1990 to 47.8 million tons in 1999.

² All estimates of historic statewide energy consumption and expenditures, unless otherwise specified, are taken from EIA databases maintained in connection with EIA's annual *State Energy Data Report* or *State Energy Price and Expenditures Report*.

³ The methodology used to estimate CO₂ emissions from fossil fuel use is discussed in a previous study, Missouri DNR, *Inventory of Missouri's Estimated Greenhouse Gas Emissions in 1990*, pp. 42-44.

⁴ As described in the introductory chapter, Short Tons Carbon Dioxide Equivalent (STCDE) is a common unit of measure that permits one to compare CO₂, methane, nitrous oxide and other greenhouse gas emissions.

Table 1a: Increase in CO₂ Emissions from Three Major Transportation Fuels, 1990-1999

	(Thousands of tons)		
	1990	1999	Percent increase
Gasoline	25,751	28,330	10%
Diesel	7,578	13,736	81%
Jet	2,971	5,712	92%
Total	36,300	47,778	32%

About 60 percent of transportation CO₂ emissions come from gasoline-fueled vehicles , primarily highway passenger vehicles.⁵ For reasons described later, technical and policy options to reduce emissions from these vehicles are the primary focus of this chapter.

The estimates in Table 1a imply that CO₂ emissions from jet fuel use increased at an annual average growth rate of 7.5 percent. This estimate is probably inflated. EIA changed its methods for collecting jet fuel consumption data during the 1990s.⁶ The resulting discontinuity in the data makes estimates of growth rate somewhat unreliable.

Nevertheless, because there were real increases in air travel and air freight shipments at Missouri's principal airports during the 1990s, it is reasonable to conclude that there was a very substantial increase in CO₂ emissions during the period. Missouri's two busiest commercial passenger airports are Kansas City International (KCI) and Lambert-St. Louis International (Lambert). During the 1990s, annual growth in air travel has averaged approximately 5.3 percent for KCI and 4.2 percent for Lambert, compared to 3 percent for the United States as a whole. Given existing and planned capacity additions, it is likely that air travel at these two airports will continue to grow at levels above national averages over the next decade.

Based on passenger miles, air travel is probably the second-most important mode of passenger travel after highway travel. Each year, more than 20 million airline passengers utilize Missouri's six commercial passenger airports: Springfield-Branson Regional, Columbia Regional, Cape Girardeau Regional, Joplin Regional, KCI and Lambert. However, due to the interstate nature of air travel, this chapter will not discuss state technical and policy options for reducing CO₂ emissions from this source.

Unlike gasoline and jet fuel, whose use is largely limited to one transportation mode, diesel fuel is used for several modes of transportation—highway, rail and water. Diesel engines power 94 percent of all freight moving in trucks, trains, boats and barges. In addition, diesel fuel powers

⁵ Gasoline also powers many light trucks and vans used for local freight delivery. However, diesel-powered trucks dominate freight movements. The larger the truck, the more miles a truck is operated each year, and the longer a truck's typical trip, the more likely it is to be diesel powered. 50 percent of light-heavy and 91percent of heavy-heavy trucks are diesel. 85 percent of trucks operated over 75,000 per year are diesel. (Data based on research by Charles River Associates sponsored by Diesel Technology Forum, http://www.dieselforum.org/news/feb_01_2001.html.)

⁶ See EIA, *State Energy Data Report* 1999, Appendix A, p. 370

more than 95 percent of all public transit buses, two thirds of all farm machinery and all heavy construction machinery.⁷

According to the estimates in Table 1a, CO₂ emissions from diesel fuel use increased very rapidly in the 1990s, at an annual average growth rate of 6.8 percent. This rapid increase reflects the expanding economy of the 1990s and Missouri's central location with respect to national and regional trucking, train and barge routes.

Nationally, interstate freight movement by truck and rail increased rapidly in the 1990s. Freight rail energy use increased about 20 percent between 1990-99 and rail car-miles traveled increased about 30 percent.⁸ Vehicle miles traveled by combination (trailer or "semi") trucks increased 40 percent and their fuel use increased by over 60 percent.⁹ Thus, it is likely that interstate freight movements by commercial transportation companies and independent truckers located outside Missouri contributed to the large increase shown in Table 1a for CO₂ emissions from Missouri diesel use.

Petroleum use and transportation are closely linked in Missouri. In 1999, according to EIA estimates, transportation demand accounted for about 80 percent of total demand for petroleum in Missouri compared to about 67 percent in the United States. Nationally, transportation's share of demand for petroleum is projected to increase to more than 70 percent by the year 2020. If Missouri follows this "business-as-usual" trend, the linkage between petroleum use and transportation will become even tighter.

Due to this close linkage, policies to reduce GHG emissions from Missouri's transportation sector are closely tied to efforts to achieve energy security and energy price stability. During 2000-2001, Missourians experienced spikes and volatility in prices and supplies of gasoline, diesel and other fossil fuels. The Missouri Energy Policy Task Force, reporting in October 2001, recommended a number of policies to encourage energy efficiency, develop renewable energy resources and adopt sustainable energy technologies with the general goal of reducing price and supply volatility and "enabl[ing] Missouri, as well as the United States, to become less dependent upon foreign sources and to expand the domestic industrial base."¹⁰

Technical Options to Reduce GHG Emissions from Highway Travel in Missouri

Emissions from highway transportation account for about 85 percent of the transportation sector's CO₂ emissions in Missouri. The remaining 15 percent derive from air, rail and water transportation and a variety of "non-highway" sources. This section reviews technical options to reduce CO₂ emissions from highway travel. Consistent with the no-regrets approach, the report

⁷ Diesel Technology Forum, http://www.dieselforum.org/news/feb_01_2001.html, based on research by Charles River Associates

⁸ U.S. Department of Energy, *Transportation Energy Data Book Edition 21*, 2001, Table 12.8. Hereafter cited as *Transportation Energy Data Book*.

⁹ U.S. Department of Transportation, Federal Highway Administration, *Highway Statistics 1999*, Washington DC 2001, Table VM1 and annual.

¹⁰ Missouri Energy Policy Task Force, *Final Report*, October 16, 2001, Introduction. The cost of oil dependence to the UNITED STATES over the past 30 years has been estimated at \$7 trillion. Greene, D.L. And N.I. Tishchishyna, *Costs of Dependence: A 2000 Update*, Oak Ridge National Laboratory, 2001.

identifies numerous ancillary benefits for the options presented including harmonized reduction of GHG and criteria pollutants.

After reviewing highway infrastructure and use and several negative consequences of continually increasing highway vehicle miles traveled (VMT), the section reviews options organized under four areas of technical opportunity: vehicle technology, vehicle management, transportation infrastructure management and the management of travel needs and trip planning.

Highway Infrastructure and Use

Missouri's highway infrastructure is extensive. Missouri, with about 123,000 miles of roadway, ranks high among states in total miles of roadway. The Missouri Department of Transportation (MoDOT) maintains more than 32,000 miles of highways and nearly 10,000 bridges in the state system. State-maintained roads constitute only 26 percent of total roadway miles in Missouri but include the National Highway System (NHS), other heavily traveled rural roads and a large percentage of heavily traveled urban roads.¹¹

The NHS, with 13 percent of total road mileage in Missouri, carries more than 62 percent of state road traffic. In addition to interstate routes, the NHS includes routes such as US Routes 36, 54, 60, 63, 65, 67 and 71. Remaining arterial roads in the state system make up another 15 percent of total state mileage and carry 20 percent of state highway system traffic.

Passenger and Freight Components of Highway Use

Highways accommodate both passenger travel and freight transportation. However, most of the miles traveled on Missouri highways are passenger miles, not freight miles. Highway travel is the primary means of passenger travel for most Missourians and is likely to be the dominant means of travel for Missourians well into this century.

MoDOT samples the use of state-maintained roads to estimate the total vehicle miles traveled (VMT) by different types of vehicles. MoDOT data indicates that in 2000, combination trucks, also known as trailer or semi trucks, accounted for about 10 percent and heavy single-unit trucks accounted for another 5 percent of total usage of state-maintained roads. Light vehicles (automobiles, light trucks, vans and SUVs) accounted for the remaining 85 percent of VMT on state-maintained roads.

Nationally, light vehicles account for almost 92 percent of all highway VMT.¹² When all roadways in the state are included, the passenger share of total VMT in Missouri probably approaches this average.

Environmental Impact of Increasing VMT

Highway vehicle miles traveled have steadily increased for decades. According to MoDOT, annual VMT on the state highway system has more than doubled since 1973. The U.S. Department of Transportation (DOT) estimates that highway vehicles traveled about 31.5 billion

¹¹ Personal communication, Alan Heckman, MoDOT, March 13, 2002,

¹² MoDOT data provided by Alan Heckman, *ibid*; U.S. DOE, *Transportation Data Fact Book*, Table 6.5.

miles on rural roads and 35.6 billion miles on urban roads in Missouri in 2000. This estimate includes all types of roads ranging from interstates to small local roads.¹³

Negative consequences of increased VMT include deterioration of the highway and bridge infrastructure, increased traffic congestion and increased emissions of criteria air pollutants.

In Missouri, as in the United States, highway vehicles are the single largest source of emissions of carbon monoxide (CO) and a major source of other urban air pollutants including volatile organic compounds (VOCs), nitrogen oxides (NOx) and toxic air pollutants. In addition, heavy-duty diesel vehicles are significant sources of sulfur oxides (SOx), and particulate matter (PM).

Criteria pollutants, unlike CO₂, directly threaten people's health. Clinical and epidemiological studies have associated ambient levels of PM, ozone, and other pollutants with human morbidity and mortality. The American Lung Association reports that even low levels of ground-level ozone adversely affect nearly one-third of our population.

Table 1b, which includes both highway and non-highway transportation, summarizes transportation's contribution to these pollutants over the past decade.

Table 1b: Transportation-related CO, NOx and VOC emissions in Missouri, 1990-99

	CO	NOx	VOC
1990	1,465,095	274,307	168,778
1991	1,769,961	295,418	189,843
1992	1,779,662	301,184	182,894
1993	1,847,613	305,874	184,704
1994	1,902,502	315,240	193,157
1995	1,491,255	296,342	161,750
1996	1,678,943	317,485	167,299
1997	1,670,005	318,294	164,391
1998	1,565,180	317,738	165,629
1999	1,521,281	311,588	164,601
Percent of 1999 statewide emissions	82%	58%	45%

On-road vehicles emit criteria and toxic pollutants in approximate proportion to each mile driven. Depending on its driving characteristics, a typical car traveling at an average speed of 25

¹³ U.S. DOT/FHWA, *Highway Statistics*, Table VM-2

mph will, in the year 2000, emit NO_x at a rate of 1.1 grams per mile (gpm), VOCs at about 1.3 gpm and CO at about 9.5 gpm.¹⁴

NO_x emissions from highway travel have increased at a 2.2 percent average annual rate during the past decade, from 168,000 tons in 1990 to 205,000 tons in 1999. Highway-related CO and VOC emissions decreased from 1.127 million tons of CO in 1990 to 1.064 million tons in 1999, and from 129 thousand tons of VOC in 1990 to 119 thousand tons in 1999.

The decrease in CO and VOC parallels a long-term national trend reflecting technological innovations spurred by the Clean Air Act. The increase in NO_x emissions also parallels a national trend; however, introduction of advanced catalytic converters may begin to force highway emissions of nitrous oxide downward.¹⁵

As will be indicated in the technical options section, most methods for reducing CO₂ emissions from highway transportation also tend to reduce criteria pollutant emissions. However, this is not universally true. Diesel use in cars and light trucks probably decreases CO₂ emissions but may increase some criteria pollutants.

Moreover, the relationship of criteria pollutant levels to fuel use is more indirect than the relationship of CO₂ emissions to fuel use. In general, highway vehicles contribute to CO₂ emissions in proportion to their total fuel use. The same is not true for criteria pollutants. A number of studies in the United States demonstrated that 10 to 20 percent of highway vehicles contribute over 60 percent of criteria pollutants. While many vehicles falling into this 10 to 20 percent category may be old vehicles with poor fuel economy that burn more than their share of fuel, there is no reason to believe that they contribute a very disproportionate share of GHG emissions.

Four Areas of Technical Opportunity

In 1999, gasoline-fueled vehicles on Missouri's highways emitted approximately 28 million tons of CO₂ into the atmosphere. This was the aggregate result of emissions from the daily use of hundreds of thousands of individually owned and operated vehicles.

A typical conventional gasoline-fueled automobile emits approximately one ton STCDE of GHG emissions per 1,800 miles of driving. However, any specific vehicle will emit more or less than this amount depending on fuel economy and the type of fuel used.

Mathematically, total CO₂ emissions from highway vehicles equals the sum of emissions from each individual vehicle. Annual CO₂ emissions from an individual vehicle can be estimated as shown in the following equation:

$$\text{CO}_2 = \text{VMT} * 1/\text{FE} * \text{C/GGE} * 44/12$$

¹⁴ State & Territorial Air Pollution Program Administrators (STAPPA) and Association of Local Air Pollution Control Officials (ALAPCO), *Reducing Greenhouse Gases and Air Pollution, a Menu of Harmonized options, Final Report*, October 1999 (referred to hereafter as STAPPA/ALAPCO), p. 112

¹⁵ According to STAPPA/ALAPCO, p. 112, use of advanced thin-walled catalysts (TWCs) and LEV/ULEV technologies results in lower nitrous oxide emissions than first generation TWCs.

Where:

CO_2 = annual CO_2 emissions from use of the vehicle;

VMT = annual vehicle miles traveled;

FE = fuel economy of the vehicle, measured in miles per gallon or miles per gallon gasoline equivalent (GGE)¹⁶;

C/GGE = carbon content of fuel, measured in pounds of carbon per gallon gasoline equivalent (GGE); and

44/12 = factor to convert pounds of carbon to pounds of CO_2 . Based on the atomic weight of the carbon and oxygen contained in carbon dioxide, CO_2 is approximately 27 percent carbon and 73 percent oxygen by weight.

As the preceding equation indicates, the level of CO_2 emissions from a vehicle is determined by the vehicle's usage (VMT), its fuel economy and the carbon content of the fuel used. If the vehicle is a dual-fueled or flexible fuel vehicle, such as most alternative fuel vehicles (AFVs) burning E85, the mix of fuels used is also a factor.

From the equation, one may infer that actions that reduce aggregate highway VMT, improve average highway vehicle fuel economy or decrease the average carbon content of highway fuel use will decrease aggregate CO_2 emissions from highway transportation.

In addition to reducing CO_2 emissions, such actions are likely to have other economic and environmental benefits. For example, improved fuel economy would reduce Missourians' out-of-pocket expenditures for gasoline and other transportation fuels. A shift to less carbon-intensive fuels would help the state reduce its dependence on imported petroleum fuels. Reduction in the growth of urban VMT could help reduce highway congestion and resolve air quality issues. Finally, reduction in the growth of VMT could help control state expenditures required to maintain roads and bridges.

At an aggregate level, highway CO_2 emissions are determined by the following four factors. Associated with each of these factors are technical opportunities for Missouri to decrease the level of highway CO_2 emissions that would otherwise occur under business-as-usual conditions.

1. **Vehicle technology.** The technological characteristics of the stock of highway vehicles in Missouri – including the mix of conventional and alternative fuel vehicles being used on the state's highways and the fuel economy of these vehicles – affects fuel economy and the type of fuel used.
2. **Vehicle management.** Driving behavior, vehicle maintenance and fleet dispatch decisions are all examples of vehicle management. Vehicle management affects fuel economy. In the case of fleets or flex-fuel vehicles, it also affects the type of fuel used.

¹⁶ GGE refers to "gallons of gasoline equivalent," a common unit of measure for transportation fuels based on the Btu content in a gallon of gasoline. Because the common unit of measure is based on gasoline, 27.5 mpg is the same as 27.5 miles per GGE for a gasoline-fueled vehicle.

3. ***Transportation infrastructure management.*** Transportation infrastructure includes both the highway system and the infrastructure for alternative modes of transportation. Highway infrastructure management affects the fuel economy of highway vehicles. The adequacy of the infrastructure provided for other modes of travel affects highway VMT by determining whether alternatives to highway travel are available.
4. ***Travel needs and trip planning.*** Highway VMT is affected by commuter and other travelers' decisions about their need for travel and their choice from available travel modes. The need for travel is influenced by individual and societal decisions about geographic dispersion of residences, workplaces and goods and services.

Vehicle Technology

Vehicle technology is a key determinant of GHG emissions from highway vehicles in the United States and in Missouri. The make and model of a vehicle largely determines the fuel economy it can achieve and the type of fuel it must use.

Fuel Economy

There are approximately 4.8 million registered highway vehicles in Missouri. Because Missouri's vehicle registration database cannot provide a meaningful breakdown of the state's current vehicle stock into vehicle types, detailed state-level data on vehicle fuel economy is not readily available.¹⁷ However, it may be assumed that the fuel economy of vehicles in use in Missouri is comparable to fuel economy for the U.S. vehicle fleet.

Between 1973 and the late 1980s, the average fuel economy of cars nearly doubled, increasing from about 14 mpg to nearly 28 mpg. Most gains in fuel economy during the 1970s and 1980s were achieved through improved technical efficiency, not by consumers moving to smaller cars.¹⁸ The improvements in fuel economy occurred in response to two factors: expectations that fuel prices would continue to be high for the foreseeable future and enactment in 1975 of Corporate Average Fuel Economy (CAFE) standards for automobiles and light trucks.

The overall fuel economy of the combined new vehicle fleet in the United States has declined about 8 percent since 1987. The sales-weighted fuel economy of new light-duty vehicles sold in the United States was 26.2 mpg in 1987 and 24.7 mpg in 2000.¹⁹ The overall decline in fleet-wide fuel economy has resulted from a change in the priority that automakers and new vehicle buyers assigned to fuel economy and a change in the overall composition of the vehicle fleet.

¹⁷ Personal Communication, Larry Rutledge, Missouri Department of Revenue, 3/14/02. There is wide variation in the categories that Missourians use in filling out vehicle registration forms. For example, pickup trucks may be registered as personal vehicles or trucks; SUVs may be registered as cars or trucks. Analysis of vehicle VINs by a company such as R.L. Polk could yield an accurate breakdown of registered vehicles but would be prohibitively expensive and is beyond the scope of this project.

¹⁸ F.W. Westbrook and Patterson, P.D. *Dynamics of Light-duty Vehicle Fuel Economy - 1978-1984, and Allocation of New Car Fuel Economy Improvements, 1976-1989*, cited in *Scenarios of U.S. Carbon Reductions*, Chapter 5.

¹⁹ Portnoy, Paul R, *The Nation's Thirst For Oil And the CAFE Standards*, Weathervane, February 11, 2002; *Transportation Energy Data Book*, Tables 7.16-7.17.

Light trucks, including vans and SUVs, with their lower fuel economy, make up an increasingly large portion of new vehicle sales and the existing vehicle fleet. Sales of light trucks, vans and SUVs now constitute over 50 percent of the new vehicle market, and use of these vehicles accounts for more than a third of the petroleum consumed annually in the United States. Pickups, vans and SUVs accounted for a 37 percent share of total U.S. light vehicle VMT in 1999, compared to a 21 percent share in 1980 and 29 percent in 1990.²⁰ In a landmark corporate citizenship report released in 2000, Ford Motor Company acknowledged that the rise of SUVs increased fuel consumption and added to greenhouse gas emissions.²¹

On the other hand, as Table 2 indicates, the average fuel economy of new automobiles has remained essentially flat since the late 1980s despite the fact that there have been significant gains in the technology embedded in new models. Technology gains have often been applied to performance enhancements like faster acceleration, more engine torque, and more overall power, rather than to improved fuel economy. For example, average vehicle horsepower has increased 46 percent since the late 1980s. An analysis of U.S. Environmental Protection Agency (EPA) data for recent model cars and light trucks indicates that although larger, heavier vehicles have greater fuel consumption per mile than smaller, light vehicles, their energy efficiency in moving the vehicle mass (weight) are similar.²²

Table 2: Fuel Economy (mpg) of New Automobiles Sold in United States, 1976-2000²³

	1976	1980	1985	1990	1995	2000	Market share
Compact, subcompact	20.2	26.6	29.8	29.8	30.7	30.7	46.6%
Midsize	15.3	21.3	24.9	25.9	25.9	26.8	37.3%
Large	13.9	19.3	22.3	23.5	24.1	25.3	14.4%
Other	20.1	26.6	28.3	27.5	25.7	25.8	1.6%
All automobiles	17.2	23.2	27.0	27.6	28.0	28.2	

Very efficient vehicles are commercially available today. For example, the Honda Insight, ranked as the most fuel-efficient car in the U.S. market, attains 61 mpg for city driving and 68 mpg on the highway. Ford's planned hybrid Escape SUV, due to be introduced in 2003, reportedly will achieve a fuel economy of 40 mpg.

However, automaker and consumer emphasis has been on factors other than fuel economy. The relatively low price of gasoline in the United States has probably been a major factor leading automakers and consumers to emphasize horsepower over fuel economy.

²⁰ *Transportation Energy Data Book*, Table 6.5. Because MoDOT monitoring equipment cannot distinguish between automobiles and two-axle, four-wheel trucks, there is no state data on the split between automobiles and "light trucks." However, it is likely that trends in Missouri closely follow those in the UNITED STATES as a whole.

²¹ Hakim, Danny, *Talking Green vs. Making Green*, NY Times, March 28, 2002

²² NRC, *Effectiveness and Impact of Corporate Average Fuel Economy Standard*, 2001

²³ Based on *Transportation Energy Data Book*, Table 7.5 ("Period Sales, Market Shares, and Sales-Weighted Fuel Economies of New Domestic and Import Automobiles, Selected Sales Periods, 1976-2000")

Alternative Fuel Vehicles

Alternative-fuel vehicles (AFVs) constitute a small but growing fraction of the U. S. vehicle fleet. Automakers have introduced or plan to introduce vehicles based on a variety of AFV technologies. Widespread market acceptance of any of these technologies as a replacement for conventional gasoline-fueled vehicles could substantially reduce CO₂ emissions from highway travel.

Automakers currently offer a number of dedicated- or flexible-fuel light-duty AFV models utilizing LPG (liquefied petroleum gases, mainly propane), E85 (85 percent ethanol), CNG (compressed natural gas), methanol or electricity as an energy source. The U.S. DOE's Office of Transportation Technology (OTT) maintains a database of commercially available models in cooperation with automakers and other original equipment manufacturers (OEMs). A complete chart listing models available in Model Year (MY) 2002 can be viewed on the World Wide Web. In addition, U.S. EPA provides Web-based information on fuel economy and other technological characteristics of available AFV models.²⁴

EIA estimates the number of AFVs in use in the United States on an annual basis, using data from their annual EIA866 survey and other sources including the Clean Cities program, the American Public Transportation Association, state energy offices, journal references and fleet managers.

EIA estimates that the U.S. vehicle fleet in 1999 included 274,000 LPG vehicles, 98,000 CNG vehicles, 40,000 E85 or methanol vehicles and 6,400 electric vehicles, out of a total fleet of more than 210 million vehicles.

While current market penetration by AFVs is small, it is clear that substitution of AFVs for conventional gasoline-fueled vehicles has the potential to reduce CO₂ emissions. In the past few years, analysts have estimated this potential using full fuel cycle models. Full fuel cycle models take into account energy use and emissions from the full fuel cycle for highway vehicles. The full fuel cycle includes vehicle end use, dispensing of fuels, fuel distribution, fuel production, transport and production of feedstocks used to produce the fuel, assembly and transport of motor vehicles and the materials used to manufacture them, the operation of maintenance and repair facilities for motor vehicles, and secondary support infrastructure for transport modes.

The AFV types most common in Missouri at this time are those fueled with propane (LPG), ethanol (E85), compressed natural gas (CNG) or methanol. As Table 3 indicates, these three types account for about 95 percent of the 7,600 AFVs which, according to EIA estimates, were in use in Missouri in 1999.

²⁴ Available on-line at http://www.afdc.doe.gov/pdfs/wModel_Year2002AFVs.pdf

Table 3: EIA Estimates of AFVs in Use in Missouri in 1999

LPG	5,060
E85	1,538
CNG	749
Methanol	274
Electric	21
	7,642

At present, the only “alternative” transportation fuel produced in Missouri is ethanol from corn. However, as further discussed in the agriculture and forestry chapter, there is potential to produce ethanol and biodiesel from crops (soy, corn) or other biomass resources in Missouri.

Using the GREET²⁵ full fuel cycle model, Michael Wang of Argonne National Laboratory has estimated the reduction in net GHG emissions that may be achieved by substituting ethanol E10 and E85 for gasoline.²⁶ Table 4 presents his estimates of the reduction achieved using E10 and E85 produced from corn (current and 2005) and cellulose (2010).

Table 4: Estimated Net GHG Reductions from Ethanol Use in Vehicles

	From Corn		Cellulose
	Current	2005	2010
E10	1%	2%	8% to 10%
E85	14% to 19%	24% to 26%	68% to 91%

Wang points out three factors that explain the reduction in GHG emissions from ethanol use. The first two factors are common to corn and cellulosic ethanol. First, ethanol has a lower carbon content per Btu than gasoline. Second, ethanol has a higher octane content than gasoline, improving engine efficiency.

The third factor is specific to cellulosic ethanol production. Cellulosic ethanol is produced from ligno-cellulosic feedstocks such as switchgrass. At cellulosic ethanol plants, the unfermentable biomass components, primarily lignin, can be used to generate steam (needed in ethanol plants) and electricity in cogeneration systems. Thus, requirements for electricity from the grid and the associated emissions from electric power plants are eliminated. Based on simulations of cellulosic ethanol production by the National Renewable Energy Laboratory (NREL), Wang concludes that cellulosic ethanol plants would generate more electric power than needed and that this excess would be exported to the electric grid, reducing emissions from other generators of electricity.

²⁵ The GREET (Greenhouse gases, Regulated Emissions, and Energy use in Transportation) Model, developed by Argonne Laboratory, estimates per-mile emissions and energy use rates for each stage in the energy cycle applicable to a particular engine/fuel combination. GREET also categorizes emissions of criteria pollutants into urban and all-location emissions.

²⁶ Wang, Michael, *Effects of Fuel Ethanol Use on Fuel-Cycle Energy and Greenhouse Gas Emissions*, Argonne National Laboratory, 1999

Wang has continued to refine GREET model analysis of ethanol and a variety of other alternative fuels and advanced vehicle technologies.²⁷ Table 5 presents some recent results. The table compares total net energy use and GHG emissions to those for a light-duty vehicle that is fueled with reformulated gasoline and achieves a fuel economy of 24.1 mpg.

Table 5: Estimated Net Full Fuel Cycle Energy Gains and GHG Reductions from Alternative Fuel and Advanced Technology Use in Vehicles

	MPG - GGE	Total energy	Total GHG
Fuel Cell: cellulosic ethanol	39.3	19.9%	-96.0%
Fuel Cell: hydrogen, central electrolysis, renewables	50.7	-37.6%	-90.7%
Ethanol (E90) from cellulosic biomass	25.3	53.8%	-77.1%
Fuel Cell: CNG	37.4	-41.6%	-51.1%
Fuel Cell: hydrogen, central plant, NG	50.7	-35.6%	-48.7%
HEV grid-connected low sulfur diesel CIDI-inject	57.7	-47.2%	-45.2%
Electric Vehicle U.S. generation mix	84.4	-45.1%	-44.5%
Fuel Cell: Methanol	42.2	-28.7%	-44.3%
HEV grid gasoline spark-inject	54.1	-40.7%	-39.9%
Fuel Cell: gasoline	37.4	-35.5%	-36.3%
Ethanol (E90) from corn	25.3	10.4%	-31.0%
Biodiesel (B20)	29.6	-19.0%	-29.0%
Compressed Natural Gas	24.1	-9.5%	-23.1%
Propane vehicle	25.3	-16.2%	-19.8%
Low sulfur diesel	29.6	-21.7%	-18.3%
Fischer-Tropsch diesel	29.6	8.7%	-14.8%
Methanol (M90)	25.3	14.6%	-5.7%
Fuel Cell: hydrogen, station electrolysis	50.7	40.5%	43.3%

As the above tables indicate, the most common AFV types used in Missouri – natural gas, ethanol and propane – achieve a 20 to 30 percent reduction in net GHG compared to gasoline use. However, the AFVs now in use represent only about 0.2 percent of Missouri’s total light-duty vehicle fleet. Much greater penetration of AFVs would be required to obtain a substantial impact on net GHG emissions from highway transportation.

The AFV technologies with greatest potential technical impact on net GHG emissions are cellulosic ethanol, electric vehicles (EVs), hybrid electric vehicles (HEVs) and fuel cell vehicles (FCVs). It should be noted that the values presented in Table 5 for these technologies assume a long-term time horizon.

²⁷ *Transportation Energy Data Book*, Table 3.6. The results shown for ethanol differ from the results shown in Table 4 due to different time frames and different assumptions about base vehicle energy efficiency.

As described in the chapter on agricultural and forestry options, there has been federal sponsorship of a number of research, development and commercialization efforts directed at cellulosic ethanol. However, at present, there is no commercial production of cellulosic ethanol. If commercial production and a supporting infrastructure develop, this would permit Missouri to rely less on imported fossil fuels and more on its own biomass resources as an energy source for transportation.

Electric vehicles (EVs) have two drawbacks: their batteries require charging, and the electric vehicles now available can travel only about 80 miles before recharging is needed. Continued improvement in battery performance is the key to success for electric vehicles.

The purchase cost for EVs, like other AFVs, commands a premium. Routine maintenance costs for EVs are lower than those for gasoline vehicles, because there are no oil changes or combustion-related wear. However, because there is a considerable amount of uncertainty surrounding the future of EVs and the ability to have them serviced, these operating cost savings are largely discounted.

The major advantages of EVs, both related to urban conditions, are as follows:

- In stop-and-start driving conditions, such as on shuttle bus routes, an EV is more efficient than a conventional gasoline-powered vehicle because its regenerative braking system captures kinetic energy during braking to recharge the battery.
- Whether idling or moving, EVs produce no local emissions of NO_x, VOC, CO or other criteria pollutants. This makes them attractive alternatives for congested urban areas that face air quality compliance issues and are trying to reduce tailpipe emissions from gasoline-powered vehicles.

Studies have estimated that the indirect NO_x emissions rate for EVs, including power plant NO_x emissions, is between a tenth and a half that of gasoline and that the indirect emissions rate for VOC and CO is negligible. EVs at present are roughly equivalent to gasoline-fueled cars in terms of total life cycle GHG emissions, and are not likely to achieve the level of GHG reductions shown in the table until 2015.²⁸

The likely result of widespread use of electric vehicles is that electric utilities would be required to increase power plant output during historically off-peak hours. While this would increase resource utilization of generation capacity, it would also increase utility emissions. Because utility emissions are centralized at the location of the plant, the geographic emission profile will be altered, not just scaled down.²⁹ This should not diminish the key environmental advantage of EVs over gasoline-powered vehicles—they do not contribute to air pollution in congested city centers in close proximity to millions of people, while power generating stations can be located in more isolated locales.

HEVs and FCVs share many of the air quality advantages of electric vehicles but have the capability to make long trips. Among the various AFV technologies, HEVs and FCVs have

²⁸ STAPPA/ALAPCO, p. 106

²⁹ Haskew, Tim and Jay Lindly, *Impact of electric vehicles on electric power generation and global environmental change*, NIGEC, 1998

received the greatest attention in federal government efforts to forge partnerships with automakers to create a large-scale transition away from gasoline-fueled highway vehicles.

Hybrid Electric Vehicles

Hybrid electric vehicles are powered by a combination of electricity and an internal combustion engine. Widespread commercial introduction of highly efficient HEVs was a focus of the Clinton administration's Partnership for a New Generation of Vehicles.

The power of an HEV's internal-combustion engine ranges from one tenth to one quarter that of a conventional automobile's but is sufficient to give HEVs the capacity to make long trips. One method to reduce engine size and increase efficiency is use of direct-injection (DI) engines. In DI engines, fuel is injected directly into each engine cylinder. Because the DI engine works in concert with an HEV's electric motor, the engine can be smaller and turned off automatically when not needed, thus increasing mileage and reducing emissions. DI engines can be fueled by either gasoline or diesel fuel.

HEV's include a range of technologies such as the following:

- An HEV may be a vehicle powered by onboard fuel which uses regenerative braking and an energy storage system that will recover at least 60 percent of the energy in a typical 70-0 braking event.
- An HEV may be an electric car that also has a small internal-combustion engine and an electric generator on board to charge the batteries, thereby extending the vehicle's range.

As this report is written, three HEV models, Honda's Insight and Civic and the Toyota Prius, are commercially available in the United States. Another dozen HEV models are either available in other countries but not the United States, or remain at the conceptual stage. An HEV is cleaner than a conventional gasoline-powered vehicle with respect to tailpipe emissions and can be made almost as "clean" as a pure electric vehicle. HEVs can achieve several times the fuel efficiency of a gasoline-powered vehicle, with a corresponding reduction in CO₂ emissions.

Fuel Cell Vehicles (FCVs)

The fuel cell is a power-generating system for electric vehicles that converts the chemical energy of hydrogen and combines it with oxygen to produce electric energy, heat and water. Vehicles powered by fuel cells have many of the advantages of electric vehicles without the disadvantage of limited range or battery replacement and recharging.

Unlike batteries, fuel cells do not store energy. Instead, fuel cells use energy stored in a fuel carried on a vehicle. Thus, the fuel cell system is restored with chemical energy rather than electrical recharging.

Major automakers have recently indicated that they intend to commit a major research and development effort to bringing FCVs to market. The federal government has announced parallel plans to expand fuel cell research, in particular through its "FreedomCAR" initiative.

Unlike the previous Partnership for a New Generation of Vehicles, the FreedomCAR initiative has not set specific targets or dates for achieving its goals. However, it is likely that interim

technical targets for advances in fuel cell performance and components such as electric drive technologies will be set through federal collaboration with automakers.³⁰

Some form of hydrogen is required for all FCVs. FCVs could carry hydrogen fuel or could operate on hydrogen produced from on-board reformers fueled with hydrogen-rich fuels such as gasoline or methanol.

The process used to create and distribute hydrogen influences the GHG impact of hydrogen-fueled fuel cell vehicles. For example, GREET analysis cited in Table 5 indicates that use of gaseous hydrogen created from centralized electrolysis using renewable energy sources would reduce GHG emissions. On the other hand, electrolysis at service stations using grid-delivered electricity generated at fossil-fired generating plants would increase GHG emissions.

Several competing systems for delivering hydrogen fuel to FCVs have been proposed by major automakers, energy companies and other stakeholders. Because it is not clear which system for delivering hydrogen fuel will become dominant in the marketplace, it is difficult to estimate the likely impact of FCVs on GHG emissions.

Potential Leverage Points for State Influence on Vehicle Technology

Most vehicles in Missouri are purchased, operated and retired by private owners. Therefore, the state has limited opportunities to influence the future composition and technological characteristics of this largely private vehicle fleet.

To assess what leverage the state does have, it is useful to consider that the future composition and technological characteristics of the stock of highway vehicles in Missouri are determined by the following three factors:

- The portfolio of advanced automotive technologies available to automakers.
- Decisions by automakers about incorporating advanced technologies into vehicles offered on the market and by their customers (both private and public sector) about which new vehicles to purchase.
- The length of vehicle life cycle to retirement.

Portfolio of Available Technologies

Even though the trend in average fuel economy since the late 1980s has been downward, the portfolio of available technologies has continued to advance since that time.

U.S. EPA estimates that only about 15 percent of the energy content of fuel burned in highway vehicles is used to move the vehicle down the road or run useful accessories like air conditioning or power steering. The remaining 85 percent of the energy supplied is wasted, as shown in the following table:³¹

³⁰ Leo, Alan, *FreedomCAR: Will It Drive?*, MIT Technology Review, January 28, 2002

³¹ U.S. EPA , <http://www.fueleconomy.gov/feg/atv.shtml>

Percent	Disposition
62%	Engine friction, engine pumping and waste heat
17%	Idling
5%	Losses in drive train due to friction and slippage

The laws of physics will not permit all of these losses to be eliminated. But every step at which energy is wasted provides opportunities for advanced technologies to increase fuel economy.

The 12.6 percent of fuel energy that makes it to the wheels must provide acceleration (5.8 percent), overcome aerodynamic drag (2.6 percent) and overcome rolling resistance. Each of these final uses of energy represents opportunities to further improve fuel economy. Reductions in vehicle mass through substitutions of high strength lightweight materials can reduce energy requirements for acceleration. Design improvements have already reduced aerodynamic drag significantly, but further reductions of 20-30 percent are possible. Advanced tire design can substantially reduce vehicle rolling resistance; the costs of advanced design have been reduced by new computational tools whose development was sponsored by U.S. DOE. As described later in this section, there are also opportunities for significant improvement in the efficiency of energy use for auxiliary loads such as climate control, power steering, entertainment systems and lighting.

Automakers have often preferred weight reduction to other technological opportunities for fuel economy because weight reduction is often the least expensive way to improve economy. Weight reduction is a source of controversy. Some analysts and stakeholders argue that weight reduction technologies inevitably reduce safety, whereas others argue that some weight reduction technologies do not necessarily have an impact on safety.³²

In any case, there are a number of other new technologies currently available that do not have a significant impact on vehicle weight. These include technologies that improve the efficiency of engines, tires, transmission and auxiliary systems.

A comprehensive inventory of available and promising automotive technologies is beyond the scope of this report. However, such inventories are readily available. As described in Appendix A, U.S. DOE's OTT provides a database of promising technologies on its Web site. EIA's National Energy Modeling System (NEMS) incorporates into its transportation sector module an inventory of technologies that might be adopted by automakers over the next 20 years. The technologies included in this modeling are periodically updated.

³² For example, Paul Portney, chair of the National Research Council's CAFÉ committee, comments that "weight reductions could be concentrated in the heavier vehicles. This would reduce the weight disparity in the fleet, which would have beneficial consequences for safety." Statement before the Committee on Commerce, Science, and Transportation and Committee on Energy and Natural Resources, U.S. Senate. Additional discussion can be found in American Institute of Physics, *The Physics of Fuel Efficiency: More MPG's Can Be Just as Safe-Even in a Lighter Car*, Scientists Say, August 2001.

Two recent major reports on transportation policy discuss the potential for fuel economy advances in the U.S. transportation sector. In 1999, a collaborative effort by five U.S. DOE federal energy laboratories used an expanded version of the NEMS “menu” of technologies to assess opportunities to reduce GHG emissions in the transportation sector through advances in vehicle technology.³³ In 2001, the National Research Council (NRC) studied the technical potential for changes in the Corporate Average Fuel Economy (CAFÉ) standard to stimulate fuel economy improvements in light vehicles, including light trucks and SUVs.³⁴ Both these reports provide an inventory and detailed discussion of advanced automotive technology.

These are only the most recent of a series of major reports over the past 25 years that have examined the technological potential to improve the fuel economy of passenger cars and light trucks in the United States. The majority of these reports used technology/cost analysis, a combination of analytical methods from the disciplines of economics and automotive engineering.

Greene and DeCicco³⁵, reviewing twenty of these studies, conclude that all of them demonstrate “at least some small potential to cost-effectively increase fuel economy beyond current market levels.” Reviewing recent studies based on time horizon, Greene and DeCicco find that studies limited to proven technologies and a time horizon of about 10 years “suggest passenger car fuel economy potentials ranging from 32 to 41 mpg, at costs in the vicinity of \$750/car (1998 dollars). Maintaining gasoline as the fuel, this efficiency potential implies reductions in per mile CO₂ emissions from vehicle use of 12 to 32 percent at a vehicle price increase of about 4 percent.”

In their review of longer-term analyses, Greene and DeCicco find “a range of 38 to 52 mpg, at costs below \$1,000 per car, implying per mile CO₂ emissions reductions of 25 to 46 percent.”³⁵

The NRC report is too recent to be included in Greene and DeCicco’s review, but its results are consistent with other studies. For example, the NRC report finds that fuel economy of midsize SUVs, which currently stands at 21 mpg, could be boosted to 28 mpg – an increase of 34 percent – over the next 10 to 15 years. This would add about \$1,250 to the purchase price of the car, but the fuel savings during the life of the vehicle would more than offset the additional cost.³⁶

Government involvement in technology research and development is most effectively coordinated and carried out at the federal level due to the national nature of the automotive industry. Accordingly, the federal government sponsors research and development (R&D) on advanced automotive technologies. For example, OTT sponsors R&D “to reduce the annual increase in the use of petroleum fuels by highway transportation vehicles to zero or less, thus reducing greenhouse gas emissions and contributing to the nation’s economy, by developing and

³³ Oak Ridge National Laboratory et al, *Scenarios for a Clean Energy Future*, Chapter 6 (Transportation Sector)

³⁴ NRC, *Effectiveness and Impact of Corporate Average Fuel Economy Standard*, 2001, Chapter 3.

³⁵ Greene, David L. and John DeCicco, *Engineering-Economic Analyses Of Automotive Fuel Economy Potential In The United States*, Annual Review of Energy & the Environment 2000. 25:477–536.

³⁶ Portnoy, op. cit., in his summary of these opportunities, highlights several specific technologies such as variable valve lift and timing and continuously variable transmissions that are capable of increasing energy efficiency by several percent.

promoting the commercialization of advanced transportation vehicles that use less petroleum as well as developing and promoting alternative fuels technologies.” OTT’s automotive technology projects include technologies suitable to conventional vehicles but focus on developing more efficient and practical natural gas, ethanol and electric vehicles. OTT also pursues projects oriented toward heavy diesel vehicles with the goal of achieving 55 percent fuel efficiency and reducing emissions from highway freight transportation.

The automotive research sponsored by OTT includes auxiliary load systems as well as automotive propulsion systems. Recent analysis showed that auxiliary loads – such as climate control, power steering, entertainment systems and lighting – could severely reduce the fuel economy of fuel-efficient vehicles. The largest auxiliary load in a vehicle is the air-conditioning system. The power required to cool a vehicle's passenger compartment can significantly reduce the range of an electric vehicle (EV) and the fuel economy of a hybrid electric vehicle (HEV). The power necessary to operate the air-conditioning compressor can be greater than the engine power required to move a mid-sized vehicle 56 km/h (35 mph). The climate control load becomes a larger percentage of the engine power as engine sizes are reduced and could reduce the fuel economy of an 80-mpg vehicle by nearly 50 percent.

Missouri’s primary role in advancing the portfolio of available technologies is through education and information to develop public support for continued research and development. There may also be opportunities for direct involvement by the state’s research institutions.

Automaker Manufacturing Decisions and New Vehicle Purchaser Decisions

The composition of the total stock of highway vehicles in Missouri is determined over time as new vehicles are purchased, used for a number of years and finally discarded. Over time, vehicles with new or improved engines or fuels replace conventional vehicles, and the advanced vehicles account for an increasing share of travel.

Thus, two types of decisions, new vehicle purchase decisions and vehicle retirement decisions, largely determine how quickly Missouri’s transition toward new vehicle technologies takes place.

In turn, purchasers can only choose between the models offered by automakers, at the cost set by automakers. Thus, decisions by automakers and their customers are closely related. Automakers incorporate new technologies based on an assessment of market and customer response. Purchasers of new vehicles, in turn, are influenced by automakers’ marketing efforts.

EIA’s NEMS includes an elaborate economic model used to project the future market share of various automotive technologies. The model was developed by analysts familiar with decision making in the auto industry.³⁷ Reduced to simplest terms, the model projects that automakers decide to introduce new technology based on four factors: manufacturing cost, fuel savings value, performance value and cost of CAFÉ compliance. The model assumes that automakers

³⁷ NEMS, created and regularly updated by EIA, is used to generate the *Annual Energy Outlook* and targeted energy policy analyses. The Transportation Sector Model (TSM) incorporates an integrated modular design based on economic, engineering and demographic relationships. In addition to the Light Duty Vehicle Module, used to estimate technological characteristics including fuel efficiency of new vehicles marketed by automakers, TSM includes five other modules and more than a dozen submodels. Full documentation of the TSM and other components of NEMS is available from EIA.

will adjust technologies to meet CAFÉ standards up to the point that doing so is cheaper than paying fines for non-compliance with CAFÉ.

Fuel Savings Value vs. Performance Value

“Fuel savings value” is based on how the change will affect fuel economy and the automaker’s assessment of how much value the customer attributes to fuel economy. Similarly, “performance value” is based on how the change will affect horsepower (a proxy for performance) and the automaker’s assessment of how much value the customer attributes to performance.

In recent years, automakers have apparently concluded that new car buyers in the United States value performance over fuel economy. Since the late 1980s, automakers have tended to incorporate innovations that increase vehicle power rather than vehicle fuel economy. According to EPA, the total fleet average horsepower for passenger cars increased in Model Year 2000 to the highest level in the 44 years for which the agency has data.³⁸ Recent automaker marketing efforts seem intended to reinforce this preference by emphasizing speed and power over fuel economy.³⁹

Most individual purchasers of new vehicles in the United States are upper income purchasers. According to a recent *Detroit News* story based on industry sources, nearly half of all new vehicles are purchased by the wealthiest 20 percent of Americans, up from 30 percent in 1995. According to industry sources, automakers have increasingly catered to this segment by offering luxury vehicles that generate “a higher margin than you make on mainstream vehicles.”⁴⁰

Institutional purchasers are another significant market segment whose influence could potentially offset an emphasis on luxury vehicles catering to upper-income individuals. Fleet managers procuring vehicles could emphasize criteria such as fuel economy and maintenance cost rather than luxury features.

CAFÉ Standards

The NEMS model includes CAFE standards as a significant factor in automaker decisions. The Energy Policy and Conservation Act instituted CAFÉ standards for cars in 1975. A lower standard for light trucks was added in 1979. The current standards are 27.5 mpg for cars and 20.7 mpg for light trucks, including vans and SUVs.

The Energy Policy Act of 1992 (EPAct) requires that each auto manufacturer attain a certain level of fuel economy in the mix of vehicles it sells in the United States. Fines are imposed on automakers that do not conform to the CAFÉ standards. The amount of the fines is based on the degree of departure from the standard. The EIA NEMS model assumes that automakers will choose to pay fines if the cost of compliance exceeds the cost of fines; however, automakers have tended to comply.

A recent review of empirical evidence on the impacts of the CAFÉ standards finds that the standards were set at levels that could be achieved by cost-effective technological innovations

³⁸ EPA , Automotive Fuel Economy Program, Annual Update for Calendar Year 2000

³⁹ Christian Science Monitor, *Zoom, Zoom... Wait a Minute*, March 21, 2002

⁴⁰ Susan Carney, “Recession or Not, Luxury Cars are Hot,” *Detroit News Auto Insider*, Jan 6 2002

and that they substantially achieved their objective of restraining U.S. oil consumption without producing significant negative side effects. The paper concludes that “properly designed and executed fuel economy regulations may be preferable to other policies for reducing petroleum dependence and carbon emissions.”⁴¹

There have been a number of proposals at the federal level to increase the CAFÉ standard for SUVs or for all vehicles.

Options for Influencing Automaker and Purchaser Decisions

The policy options section of this chapter includes a number of options to influence decisions by automakers and purchasers, including the following:

- Support the institutional market for AFVs and fuel-efficient vehicles through fleet vehicle procurement policies. Missouri law requires state agencies to purchase only passenger vehicles whose fuel economy is at least equal to the CAFÉ standard and to meet specific schedules for adding AFVs to state fleets. As described in the policy section, there are additional options to emphasize efficiency and alternative fuels in the management of state and other public fleets.
- Pursue additional means such as public-private partnerships to support the institutional market for AFVs and fuel-efficient vehicles.
- Consider mandatory federal measures such as increases in the CAFÉ standard.
- Support voluntary regional or federal efforts to influence automakers such as partnerships, voluntary agreements and informal discussions with automakers. Missouri’s role in such efforts would likely be as supporter or collaborator rather than initiator.
- Influence purchasers through public information to promote consumer understanding, acceptance and preference for vehicles achieving high fuel economy or utilizing alternative fuel technologies.
- Provide economic incentives for purchasers of new technology vehicles. The policy options section recommends that incentives be approached cautiously due to their uncertain and potentially large financial impact.

End of Vehicle Life Cycle

Once a new vehicle has been introduced to the “stock” of vehicles in Missouri, it may change ownership but remains in use until retirement. Based on data developed by analysts at Oak Ridge National Laboratory (ORNL), the expected median lifetime for an automobile in the United States is about 16 years.

In 2000, assuming that ORNL’s estimates apply to Missouri, over 99 percent of the 1970 model year and about 86 percent of 1980 model year vehicles that were once in Missouri’s fleet had

⁴¹ Greene, David L., *Transportation Energy and Environmental Policy: Why CAFÉ Worked*,” Oak Ridge National Laboratory, June 1998.

been retired. However, fully 84 percent of 1990 model year vehicles were still in active use, and about 50 percent will remain in active use by 2005.⁴²

Programs that encourage earlier retirement of old vehicles would be likely to significantly improve mobile source pollution amounts. Numerous studies in the United States have demonstrated that only a small fraction of on-road vehicles (e.g., 10-20 percent) contribute most pollution (e.g., over 60 percent). Tests during the 1990s on thousands of vehicles in Los Angeles, Chicago and elsewhere indicated that 50 percent of all carbon monoxide emissions come from only 10 percent of the cars on the roads. Similarly, 14 percent of vehicles accounted for half the hydrocarbons leaving tailpipes. Vehicles falling into this highly polluting group tend to be older vehicles, particularly the few pre-1971 vehicles left on the road.

Early retirement programs would probably reduce CO₂ emissions as well. However, the reduction of CO₂ emissions would not be as dramatic as the reduction in criteria pollutant emissions. Assuming no change in VMT, the amount of a vehicle's CO₂ emissions depends only on fuel economy rather than other characteristics of the combustion process. Therefore, an early retirement program would benefit the amount of CO₂ emissions only to the extent that older vehicles have poorer fuel economy than newer vehicles that replace them.

Vehicle Management

The great majority of highway vehicles in use in Missouri at any given time are not new vehicles. Having been purchased and brought into the state's stock of vehicles, their technological characteristics are largely set until they are retired. However, the in-use fuel economy of vehicles can be higher or, as is usually the case, lower than the rated fuel economy of the vehicle model. Driving behavior, maintenance practices and other vehicle management practices of individual owners and fleet managers affect the actual fuel economy of these vehicles.

In addition, fleet managers whose fleets include flexible-fuel vehicles or a mix of conventional vehicles and AFVs have some flexibility to determine the actual mix of fuel used by adjusting their vehicle dispatch decisions and fueling policies.

Improved Driving Behavior

Numerous studies have shown that improved driving behavior can lower fuel consumption by 10 to 15 percent or even more.⁴³ U.S. EPA estimates that aggressive driving (speeding, rapid acceleration and braking), besides endangering the driver and others, can lower the vehicle's gas mileage by 33 percent at highway speeds and by 5 percent around town.

Gas mileage decreases rapidly above the optimal speed of 55-60 mph.⁴⁴ U.S. EPA estimates the fuel economy benefit from observing speed limits at 7 to 23 percent. As a result, speeders pay more for gasoline in addition to endangering themselves and others. Use of cruise control and

⁴² *Transportation Energy Data Book*, Table 6.9

⁴³ For example, an estimate of 20 percent is given by the National Roundtable on Environment and Economy (NRTEE), and Ontario Roundtable on Environment and Economy (ORTEEE). 1995. A Strategy for Sustainable Transportation in Ontario: Report of the Transportation and Climate Change Collaborative. November 1995, p.16.

⁴⁴ *Transportation Energy Data Book*, Table 7-22

overdrive gearing both contribute to fuel conservation on the highway. Cruise control helps maintain a constant speed and, in most cases, saves fuel. Overdrive gearing reduces engine speed, saving fuel and reducing engine wear.

Idling achieves a fuel economy of 0 miles per gallon. Effective highway management, by reducing factors such as highway congestion and delays due to accidents, can reduce idling. Other reductions of idling depend on changes in driver behavior. In addition, staggering work hours to avoid commuting during peak rush hours can reduce commute trip idling in congested traffic.

Fuel-efficient driving techniques include driving smoothly, less aggressive acceleration and deceleration, driving at optimal vehicle cruise speed, shifting gears earlier, using more coast-down driving, turning off the engine during long waiting and predicting the change of traffic lights from green to red in advance so that the vehicle approaches the intersection slowly.

Missouri's primary opportunity to influence driver behavior is through driver training programs. Effective driver training programs can reduce fuel consumption while achieving other benefits such as increased roadway safety.

Improved Vehicle Maintenance

Proper vehicle maintenance is a critical factor in the ability of a specific vehicle to achieve or surpass its rated fuel economy. The following examples illustrate the potential fuel economy benefits of proper maintenance.

- Engine tuning: Fixing a car that is noticeably out of tune or has failed an emissions test can improve its gas mileage by an average of 4.1 percent, though results vary based on the kind of repair and how well it is done. If the car has a faulty oxygen sensor, a tune-up can improve gas mileage by as much as 40 percent.
- Regular air filter replacement: Replacing a clogged air filter can improve the vehicle's gas mileage by as much as 10 percent. The air filter keeps impurities from damaging the inside of the engine. Not only will replacing a dirty air filter save gas, it will protect the engine.
- Proper inflation of tires: Gas mileage can improve by around 3.3 percent by keeping tires inflated to the proper pressure. Under-inflated tires can lower gas mileage by 0.4 percent for every 1 psi drop in pressure of all four tires. Properly inflated tires are safer and last longer.
- Use of recommended grade of motor oil: Use of the manufacturer's recommended grade can improve gas mileage by 1-2 percent. For example, using 10W-30 motor oil in an engine designed to use 5W-30 can lower gas mileage by 1-2 percent. Using 5W-30 in an engine designed for 5W-20 can lower gas mileage by 1-1.5 percent. Motor oil that says "Energy Conserving" on the API performance symbol contains friction-reducing additives. New modified or slippery oils are designed to improve mileage by as much as 3 to 8 percent.

Together, proper engine tuning, tire inflation, air filter replacement and use of the recommended oil increase a vehicle's fuel economy by about 15 percent compared to an improperly maintained vehicle. In some instances, the gain can substantially exceed 20 percent. On average, a 10 percent fuel economy gain can be expected.⁴⁵

⁴⁵ Based on experience of a specialist with five years experience running a vehicle maintenance program, cited at

The vehicle owner can further improve fuel economy by maximizing aerodynamic efficiency. For example, although a roof rack or carrier provides additional cargo capability, a loaded roof rack can decrease fuel economy by 5 percent. Other fuel economy-killers include “aggressive” tread tires, carrying unnecessary weight and excessive use of air conditioning.

Missouri’s primary opportunity to influence private sector vehicle maintenance is through information, training and incentives. The enhanced inspection and maintenance program established for other purposes in the St. Louis area can also promote better vehicle maintenance.

Managers of public fleets in the state can improve maintenance of their own fleet and where appropriate, include fleet management as an aspect of partnerships or collaborative efforts with the private sector.

Public Fleet Management

Fleet dispatch, routing and tracking has developed into a specialized area of management. Several private-sector carriers in Missouri are at the national forefront in the deployment and use of fleet management and freight management systems. These systems provide better utilization of resources, resulting in lower operational costs and improved customer satisfaction.

Increasingly, state agency, local government, school district and other public fleets as well as private fleets include a mix of conventional vehicles, dedicated AFVs and flexible fuel AFVs. Fleet managers determine the usage of AFVs and the relative mix of less- and more-carbon-intensive fuels through dispatch and fueling policies and decisions, and could develop policies and procedures that assure maximum use of AFVs and low-carbon fuels consistent with the principles of efficient fleet management.

Infrastructure Management and Alternative Modes of Transportation

In general, it is the responsibility of state, regional and local transportation authorities to provide and manage highways, bridges and other “infrastructure” elements of highway transportation. Public authorities also have a large part to play in providing the infrastructure for other modes of transportation – air, rail, water and the various modes of public transit.

The management of transportation infrastructure is an important determinant of GHG emissions, for the following reasons:

- The efficiency of the state’s transportation system can be enhanced by a variety of highway management techniques including Intelligent Transportation Systems (ITS).
- A reduction in highway VMT can occur if travelers switch to alternative modes of travel. At minimum, the necessary physical infrastructure for alternative modes such as light or heavy rail must be in place.

For convenience, some travel demand management techniques that do not directly involve the management of physical infrastructure are nevertheless included in this section. Examples include promoting car pools, public transportation and flexible work schedules. Similarly, features and incentives that make these alternative modes more practical or attractive, or that otherwise encourage travelers to use these modes, may be considered here.

<http://www.climatechangesolutions.com/english/individuals/opportunities/transport/default.htm#linkout>.

Highway management can involve policy questions as well as infrastructure management. Emission reductions may be an ancillary benefit of policy decisions that are primarily driven by other considerations. For example, highway speed limits are set by balancing a variety of factors related to driver behavior and safety. The most recent available data indicates that on average, highway vehicles operate most efficiently at a speed of about 55 mph. On average, an increase in vehicle speed from 55 mph to 70 mph reduces vehicle fuel economy by about 17 percent. When speed limits are set at a level at which actual speed approaches optimal speed, vehicle fuel efficiency is optimized, reducing emissions.⁴⁶

One caveat that applies to many infrastructure management techniques is that they will effectively reduce CO₂ emissions from the business-as-usual level only if the demand for highway travel is limited. If the response to highway improvements and/or the diversion of travelers to other modes is simply to stimulate more highway travel – a phenomenon known as induced demand – there is little reason to expect vehicle fuel economy to improve or highway VMT to decrease.

Advanced Highway Management

Energy efficiency is one among multiple goals, including safety and convenience, that determine highway management policies and practices. However, policies and practices that focus primarily on other goals frequently improve energy efficiency. Any improvement in highway energy efficiency reduces GHG emissions compared to emissions that would otherwise occur.

Because 9 billion gallons of fuel are wasted in U.S. traffic congestion each year, efforts to reduce congestion are likely to enhance energy efficiency.⁴⁷ An example is traffic signal coordination. By synchronizing traffic signals it is possible to create a “signal green wave.” Coordinated lights may be accompanied by the implementation of appropriate one-way roads. This technique tends to reduce GHG emissions by improving traffic flow.

Similarly, efforts to improve highway safety are likely to benefit energy efficiency by reducing accident-related traffic congestion.

The state, led by MoDOT, has undertaken a commitment to implementing Intelligent Transportation Systems (ITS) that will accomplish some of these objectives. ITS refers to a diverse range of transportation system management initiatives that incorporate advanced technology to solve transportation problems and provide benefits such as safety and congestion reduction.

MoDOT has nearly completed a multi-year planning process for statewide deployment of ITS systems. Other agencies involved with ITS deployment in Missouri include cities, metropolitan planning organizations, transit agencies, the Federal Highway Administration (FHWA), and the Federal Transit Administration.

Typically, ITS solutions to transportation problems are integrated into a package that includes design/policy strategies and may include infrastructure improvements.⁴⁸ For example, an ITS

⁴⁶ Transportation Energy Data Book, Table 7.22

⁴⁷ Statistic taken from EPA Commuter Choice web site at <http://www.commuterchoice.gov/about/facts.htm>

⁴⁸ MoDOT, *Incorporating ITS Into the Planning Process*, no date.

component such as an automated enforcement program could be deployed in conjunction with a speed limit policy to increase compliance with the policy.

Because ITS initiatives use diverse technologies to achieve diverse goals, it has been necessary to create a taxonomy of ITS initiatives. U.S. DOT has created a taxonomy that categorizes ITS technologies into “market packages” that represent logical assemblies of different technologies and subsystems that are deployed to achieve specific purposes, either as stand-alone projects or as part of larger infrastructure projects.

MoDOT, using U.S. DOT categories, has published a report⁴⁹ that describes each market package and its associated technologies and benefits. In addition, MoDOT has developed a performance-based methodology to rank and select market packages for deployment in Missouri. MoDOT ranks technology focus areas based on the following six benefit categories as well as institutional considerations:

1. Improved traveler safety
2. Reduction in travel time
3. Reduction in emissions
4. Reduction in agency costs (improved agency efficiency)
5. Reduction in user costs (fuel use)
6. Improved customer satisfaction (improvement in traveler comfort and security).

Of these benefit criteria, MoDOT assigns the highest weight to safety (14 points) and the lowest weight to reduction in emissions and fuel use (4 points each). However, as previously discussed, ITS may achieve emissions reduction and fuel conservation as ancillary benefits even if selected and deployed for other reasons.

Since December 1994, U.S. DOT’s Joint Program Office for Intelligent Transportation Systems has actively collected information on the impact of ITS projects. Data collected under this effort is available on-line in the ITS benefits database.⁵⁰

Based on a review of data from the ITS database, MoDOT’s *Statewide Integrated ITS Business and Deployment Plan* and other sources, four types of ITS implementations appear likely to decrease wasteful energy use and reduce CO₂ emissions from highway travel. These are advanced traffic management systems, advanced transit management systems, advanced traveler information systems and advanced incident management systems.

Advanced Traffic Management Systems encompass a variety of ITS market packages whose potential benefits include increased productivity due to time and cost savings, decreased emissions of criteria pollutants and more efficient fuel use.

Studies indicate that freeway management systems may lead to modest levels of fuel conservation. However, the greatest proven fuel saving potential belongs to systems that improve and coordinate traffic signal control on arterial roadways. Studies of coordinated signals have

⁴⁹ MoDOT, *Statewide Integrated ITS Business and Deployment Plan, Market Package Report*, October 2001; hereafter cited as *Market Package Report*.

⁵⁰ <http://www.its.dot.gov/>

found that traffic delays are reduced by 14 to 44 percent, stops by 10 to 41 percent, travel time by as much as 20 percent and fuel use by 2 to 13 percent. One study of 163 different signal timing projects found an average fuel use reduction of 7.8 percent.

Missouri has more than three decades of experience with coordinated traffic signals, including grant-funded pilot projects in the early 1990s. To date, about 240 systems have been deployed throughout the state; about 60 percent of the traffic signals operated by MODOT are coordinated.

An arterial traffic management system in Springfield, MO that is cooperatively operated by the city and MoDOT allows traffic management personnel to adjust signal timing based on real time traffic conditions along several corridors. The corridors are equipped with closed-circuit cameras installed at key intersections. When corridor congestion is detected, several mitigation strategies are available to personnel at the traffic operations center. Various coordinated traffic signal timing strategies may be implemented through an interconnected signal system. Personnel may continue to monitor corridor congestion and make further modifications to the arterial timing patterns as warranted.

Similarly, the KC Scout project in Kansas City and the Gateway Guide project in St. Louis are planned to provide improved freeway management based on greatly enhanced capabilities for monitoring and reacting to real time traffic conditions. Closed circuit cameras and other detection capabilities will provide surveillance for recurring and non-recurring congestion, and allow for improved operations of other related ITS components, including the incident management system and traveler information systems.

Advanced Transit Management Systems increase the attractiveness of transit as a viable transportation mode by improving schedule reliability, reductions in travel time, enhancements in trip planning and improved safety from assault. Bus fleet operations also become more efficient. These improvements result in a wide variety of community and societal benefits including greater ridership by users who might otherwise rely on highway vehicles.

Electronic fare payment systems, by increasing the attractiveness of public transportation, may similarly decrease highway VMT and CO₂ emissions.

In Missouri, Advanced Transit Management is being deployed in Kansas City, where a transit management system with computer-aided dispatch and automatic vehicle location (AVL) was evaluated in the early 1990s. The evaluation found a 12 percent improvement in on-time performance and positive impacts on schedule reliability and operational efficiency. The Kansas City Area Transportation Authority is currently in the process of upgrading its AVL system.

Advanced Traveler Information Systems reduce travel time, delays and variability while providing an overall improvement in commuter comfort. Studies have also indicated that accidents are reduced by 15 to 28 percent through the use of safety-related traveler information systems. Several studies indicate that many travelers are likely to shift modes from personal vehicles to transit when provided with transit information. Several studies performed in the United States and Europe have reported reductions in hydrocarbons (HC), nitrogen oxides (NO) and carbon monoxide (CO) emissions ranging from 1 to 25 percent. Studies performed in the United States and Japan have reported a reduction in fuel consumption ranging from 2.6 to 11 percent.

One implementation of a Traveler Information System in Missouri is the Branson Travel and Recreation Information Program (TRIP), which features a Web site that provides a single source

for travel information including traffic, weather and roadway construction conditions. This information is also available via a call-in telephone service and stationary kiosks in the Branson area. The system allows tourists to make better-informed decisions regarding the time, route and destination of their travel. However, the TRIP system as presently implemented provides no transit information and therefore is unlikely to result in mode shifting.

Advanced Incident Management Systems result in increased safety (10 percent reduction in fatality accidents for facilities with incident detection and management systems), increased travel time reliability, increased system throughput (55 percent reduction in incident back-up duration) and delay reductions ranging from 95,000 to 2 million hours per year. One study estimated that fuel use and emissions caused by incident-related congestion was reduced by 42 percent.

Motorist assist programs in St. Louis and Kansas City provide an example of successful incident management initiatives. The motorist assist vehicles respond to incidents, assist vehicle breakdowns, clean-up spills, remove roadway debris and remove abandoned vehicles. Other key components of the St. Louis program include real-time traffic information for motorists, coordination with “key community partners,” and incident management training for the 51 communities that border the interstate.

These programs have been very successful in helping to prevent incident-induced traffic congestion. It is estimated that MoDOT assists approximately 30,000 vehicles a year in the St. Louis region and 7,000 vehicles annually in the Kansas City region. There are plans to expand the programs in St. Louis and Kansas City. Other regions are considering their own programs.

Several other types of ITS reduce the fuel waste associated with delays that now occur due to accidents, toll collection or weigh station requirements.

Electronic Toll Collection (ETC) Systems reduce traffic delays while also reducing the operating costs of collecting tolls by 34 to 91 percent while reducing traffic delays. Several bordering states (Illinois, Kansas and Oklahoma) maintain significant toll facilities and have implemented ETC technologies. ETC systems have few direct applications in Missouri at present due to the absence of tolled facilities. However, ETC might be used for Lake of the Ozarks Community Bridge, a toll bridge in the Lake of the Ozarks region.

This section has discussed ITS systems that are implemented at a transportation system level. There are also ITS devices installed in individual vehicles to address collision avoidance, driver safety monitoring, vehicle safety and condition monitoring, vision enhancement and safety readiness. These devices are sold by automakers and after-market automobile electronics providers and are increasingly being offered as standard equipment on selected models. No data is available concerning the impact of these devices on vehicle energy use. Their deployment is led by the private sector with little role for the state.

Improved Availability and Attractiveness of Alternatives to Single-Occupant Vehicle (SOV) Trips

As Table 6 on the following page indicates, drive-alone trips in automobiles and light trucks, also known as single occupant vehicle (SOV) trips, are the most energy- and CO₂-emissions intensive of all the common modes of passenger travel in the United States⁵¹

Over the past several decades, the average number of riders per highway vehicle, also known as vehicle load factor, has tended to decline. This has occurred due to demographic changes and the increasing geographic dispersion of residences, workplaces, and goods and services. Household travel surveys by the FHWA indicate a long-term decline in vehicle load factor from 1.9 passengers per vehicle in 1977 to 1.6 passengers per vehicle in 1990. A revised estimate for 2001 is now being compiled by FHWA.

Drive-alone trips are particularly common among commuters. In the United States, three-quarters of all trips made to and from work are in single-passenger vehicles.⁵²

Table 6: Energy Intensity (Btu per passenger-mile) of Common Passenger Travel Modes⁵³

	Auto SOV	Light truck SOV	Local Bus	Local Light Rail	Certified Air Carrier	Inter-city Rail	Inter-city Bus
1970	9,301	12,492	2,472	2,453	10,351	N/A	1,674
1975	9,015	11,890	2,814	2,962	7,883	3,677	988
1976	9,130	11,535	2,896	2,971	7,481	3,397	1,007
1977	8,961	11,171	2,889	2,691	7,174	3,568	970
1978	8,844	10,815	2,883	2,210	6,333	3,683	976
1979	8,647	10,473	2,795	2,794	5,858	3,472	1,028
1980	7,915	10,230	2,813	3,008	5,837	3,176	1,082
1981	7,672	10,001	3,027	2,946	5,743	2,957	1,051
1982	7,485	9,275	3,237	3,069	5,147	3,156	1,172
1983	7,376	9,141	3,177	3,212	5,107	2,957	1,286
1984	7,218	8,945	3,204	3,732	5,031	3,027	954
1985	7,182	8,754	2,421	3,461	5,679	2,800	964
1986	7,213	8,578	3,512	3,531	5,447	2,574	870
1987	6,975	8,376	3,542	3,534	4,751	2,537	940

⁵¹ Travel in airplanes not operated by certified air carriers is about twice as energy-intensive as highway SOV travel. However, this mode of travel is not commonly available to most Missourians and therefore is not shown in the table.

⁵² EPA Commuter Choice web site, as previously cited.

⁵³ Compiled from *Transportation Energy Data Book*, Tables 2.11 and 2.12

1988	6,700	8,155	3,415	3,585	4,814	2,462	963
1989	6,602	7,778	3,711	3,397	4,808	2,731	964
1990	6,183	7,773	3,735	3,453	5,006	2,609	962
1991	5,925	7,381	3,811	3,710	4,595	2,503	963
1992	5,969	7,262	4,310	3,575	4,482	2,610	964
1993	6,103	7,207	4,262	3,687	4,558	2,646	962
1994	6,041	7,232	4,609	3,828	4,336	2,351	964
1995	5,923	7,236	4,643	3,818	4,282	2,592	964
1996	5,893	7,269	4,675	3,444	4,096	2,783	963
1997	5,821	7,277	4,744	3,253	4,044	2,923	963
1998	5,771	7,288	4,688	3,216	3,981	2,892	963
1999	5,815	7,343	4,610	3,168	3,889	3,063	964

Alternative Modes for Intercity Travel

This section discusses public transportation alternatives for intercity and other long-distance travel. Intercity bus service is the least energy intensive highway passenger mode available, with an average energy intensity less than one thousand Btu per passenger-mile. The average energy intensity for intercity train, about 3,000 Btu per passenger mile, is comparable to that for light rail. Both modes are more energy efficient than intercity travel in an SOV highway vehicle.⁵⁴

Most intercity bus service in Missouri is offered by a private carrier, Greyhound Lines. In addition to the intercity bus services provided by Greyhound Lines, one intercity bus line operated by Sho-Me Coaches offers transportation between Columbia and Springfield with financial support by MoDOT.

Amtrak offers two eastbound trips and two westbound trips daily between St. Louis and Kansas City, with a maximum speed of 79 mph. The scheduled travel time between these cities is 5 hours 40 minutes. Amtrak also offers access to the Texas Eagle route with daily service between Chicago and Dallas and the Southwest Chief route with daily service between Chicago and Los Angeles. These routes in turn offer connections to any Amtrak route in North America.

Increased travel on Missouri highways and at major airports has resulted in a renewed interest in intercity rail passenger service. A number of initiatives are investigating higher speed rail service opportunities between Kansas City and St. Louis. One of the more prominent initiatives is the Midwest Regional Rail Initiative (MWRRI), a collaborative effort among nine Midwest states including Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Nebraska, Ohio and Wisconsin.

⁵⁴ An automobile or van loaded with multiple passengers would achieve better energy efficiencies than listed here. For example, an automobile loaded with 6 passengers would probably achieve performance (Btu per passenger-mile) comparable to that for an intercity bus.

In its Missouri Long-Range Transportation Direction (LRTD), MoDOT concluded that the state's most important passenger rail needs could be met by implementing the Midwest Regional Rail Initiative on existing rail tracks with modifications between St. Louis and Kansas City. Challenges in establishing the proposed system include obtaining the necessary funding and seamless integration with the freight rail system.

Alternative Modes for Commuting and Local Travel

This section discusses several methods for reducing energy use and GHG emissions associated with local SOV trips. The methods include the following:

- Increasing the load factor (passengers per vehicle) in commuter trips through car pooling, van pooling and other methods to increase multiple-occupant vehicle-trips.
- Substituting alternative travel modes such as pedestrian, bicycle or public transportation that are less energy- and CO₂- intensive than SOV travel.
- Substituting telecommunications technology for physical travel through teleconferencing and telecommuting.

Multiple-Occupant Vehicle Commuting Trips

Car and vanpooling is a common, voluntary, low-cost method used by commuters to reduce commuting costs. It may be as simple as an agreement between co-workers who live on the same route to work. A commuter can cut weekly fuel costs in half and reduce vehicle wear and maintenance by taking turns driving with other commuters.

Car and vanpooling have public benefits that extend beyond cost cutting. Consolidating SOV trips into one through ridesharing decreases energy use by a factor based on the number of trips consolidated. Consolidating two SOV trips into one two-person trip, for example, should approximately cut energy use and CO₂ emissions in half while also reducing traffic congestion and the emissions of criteria pollutants.

State and local government can support car and vanpooling by providing information about the benefits of ridepooling, helping potential riders find each other through rideshare programs, and providing commuter lots to facilitate ridesharing.

Missouri, like many other states, has had years of experience with rideshare programs. The Department of Natural Resources' Energy Center operates a rideshare information program in mid-Missouri and funds a Kansas City rideshare information program operated by the Mid-America Regional Council (MARC). Municipal transportation authorities have long operated a rideshare program in St. Louis.

MoDOT sponsors park-and-ride commuter lots around the state that permit commuters to meet at a common spot and share rides or use public transportation for the remainder of the commuting trip.

Some states and cities have established high-occupancy vehicle (HOV) lanes to encourage ridesharing. MoDOT and regional transportation authorities have explored this option but for legal and practical reasons no HOV lanes have been established in Missouri.

Another measure that can encourage carpooling among employees at workplaces in congested areas is establishment of a parking voucher system that compensates workers who choose efficient non-SOV modes for commuting. Parking voucher systems, also known as “cash out” systems, have been implemented by employers who provide employees with the cash value of parking. Employees are allowed to spend the money on other modes of travel. The Tax Relief Act of 1997 changes the U.S. tax code to allow employees to accept cash in lieu of parking benefits.⁵⁵

Public Transit

Transit includes all public forms of passenger transportation by bus, light rail and van, including fixed-route services and paratransit services operated specifically for persons with disabilities and elderly persons. “Light rail” refers to post-1970 urban train systems that are normally powered by overhead electrical wires and are able to board and discharge passengers at station platforms or at street, track or car-floor level. They may run on ground, underground or on aerial structures.

Public transportation systems in Missouri provide more than 70 million passenger trips annually. The system ranges from a large multimodal transit system in the St. Louis area to one-vehicle systems in rural areas.

Comparisons of average energy intensity of SOV and transit travel, measured by Btu per passenger-mile, offer a rough indicator of potential energy efficiency gains from transit use. As Table 6 indicates, DOE has estimated that the average energy intensity for a light truck SOV is 7,300 Btu per passenger-mile and for an automobile is 5,800 Btu per passenger-mile.

While the average energy intensity of transit bus service is still lower than that for highway SOV travel, it has tended to increase since 1970. Average transit bus energy intensity was 2,500 Btu per passenger-mile in 1970, 3,200 Btu in 1984 and 4,600 Btu in 1999. Reasons for these trends include increasing traffic congestion and declining bus ridership.

However, the transit bus energy intensity varies by city. For example, in St. Louis, the average energy intensity is less than 3,000 Btu per passenger mile, comparable to the national average for light rail.⁵⁶

The average energy intensity of transit rail (light rail) service, like that of transit bus service, increased until the mid-1980s, then fluctuated. The recent trend toward decreasing energy intensity probably reflects recent installations of more advanced and efficient light-rail systems. Average transit rail energy intensity was 2,500 Btu per passenger-mile in 1970, 3,700 Btu in 1984 and 3,200 Btu in 1999.

All other things being equal, as the load factor for transit systems increases, they become more energy efficient. As with any other transportation mode, a fully loaded bus or light rail train is

⁵⁵ STAPPA/ALAPCO, p. 110.

⁵⁶ *Transportation Energy Data Book*, Table 8.12 and Figure 2.3. In the case of transit systems serving similar populations, energy intensity can be considered to measure energy efficiency. In other cases when the service provided is not homogeneous it can be misleading to assume that energy intensity measures efficiency. For example, a transit system serving a rural area may offer a service that is very energy efficient for what is being done, but still energy intensive because it is serving a population that is geographically dispersed.

more energy efficient than one carrying only a few passengers. Thus, transit energy efficiency should increase as ridership increases.

Despite numerous attempts to promote bus transit, the overall U.S. trend over the past 20 years has been toward decreasing bus ridership. Since 1984, total passenger-miles have remained constant at about 21 billion while the number of active buses and number of vehicle miles have both increased. Light rail, on the other hand, has increased in popularity.

The Metrolink light rail system in St. Louis carries about 40,000 riders on an average weekday, making it the second busiest light rail system in the nation after San Diego. The Metrolink system began operating in St. Louis in July 1993 with 18 miles of track and 18 stations. It was built on existing railroad rights-of-way, structures, facilities and nearly 14 miles of railroad tracks that had been unused for decades. The system serves Lambert/St. Louis International Airport and a number of stations in St. Louis and has proven highly popular.

Of the more than 70 million trips taken on Missouri's public transportation systems annually, the majority occur in the large urban transit systems of St. Louis and Kansas City. The St. Louis transit system, which includes Metrolink as well as a large fleet of transit buses, is operated by the Bi-State Development Agency (Bi-State). The Kansas City transit system, which does not include light rail, is operated by the Kansas City Area Transportation Authority (KCATA).

Small urban systems include public transportation systems in Springfield, St. Joseph, Columbia, Joplin and Jefferson City. These provide fixed route and demand response transit service to the general public.

Rural public transportation systems in Missouri include numerous transit and para-transit service providers that focus on serving social needs such as access to medical and nutritional services for the elderly or disabled. Rural transportation systems range in size from OATS, Inc., which operates 300 vehicles in 87 counties, to one-vehicle systems providing single purpose trips. Very few work commute trips are made by public transportation in rural areas.

Public transportation is infrastructure-intensive. In preparing its Long-Range Transportation Direction, MoDOT assessed the state's public transportation needs and estimated the funding required to meet these needs. The MoDOT estimate of funding needs is as follows.

Table 7: Funds Required to Meet Missouri's Statewide Public Transportation Need (in millions)

	Preservation			Expansion			Total
	20-Year Capital	20-Year Operating	Total	20-Year Capital	20-Year Operating	Total	Grand Total
Large urban	1,264	3,120	4,384	2,576	604	3,180	7,564
Small urban	93	213	307	142	191	333	640
Rural	72	142	214	112	180	292	507
Total	1,430	3,476	4,906	2,830	976	3,806	8,711

Engineering studies are underway to extend Metrolink, with financing provided by a quarter-cent increase in the sales tax and by federal funds.

Several other proposals to extend light rail in St. Louis or Kansas City have failed to achieve necessary funding and approval by all communities involved. For example, in August, 2001, a half-cent sales tax to fund a Kansas City light rail system failed at the polls. The proposal for a 24-mile, \$793 million north-south light rail system had been developed through a three-year cooperative planning effort by the KCATA and the cities of Kansas City, MO and North Kansas City. The proposed line would have provided service to the region's most densely populated areas while allowing expansion in all directions.

Pedestrian and Bicycle Travel

By their nature, pedestrian and bicycle travel are less energy-intensive than any other mode of travel, public or private, because they require no fuel input. Pedestrian and bicycle travel is also far less infrastructure-intensive than public transportation.

However, pedestrians and bicyclists do have infrastructure needs. Pedestrians need sidewalks, crosswalks at appropriate locations and curb ramps. Bicyclist needs include infrastructure such as bicycle lanes, signage and convenient and safe bicycle racks as well as education, enforcement, technical assistance and policy adoption at the national, state and local levels. Both bicyclists and pedestrians need convenient, safe access to other modes of transportation.

Both pedestrians and bicyclists can benefit from walkable communities that locate within an easy and safe walk to goods (such as housing, offices and retail) and services (such as transportation, schools and libraries) that a community resident or employee needs on a regular basis. By definition, walkable communities make pedestrian activity possible, thus expanding transportation options and creating a streetscape that better serves a range of users – pedestrians, bicyclists, transit riders and automobiles. Community characteristics that foster walkability include mixed use of geographic space, compactness and the assurance of safe and inviting pedestrian corridors.

The personal and societal benefits of pedestrian and bicycle friendly communities include lower transportation costs, greater social interaction, improved personal and environmental health and expanded consumer choice.

Promoting Multi-Modal Connectivity of Alternative Transportation Modes

Multi-modal connectivity is key to the success of the alternative modes of transportation discussed here. Within communities, pedestrians, bicyclists and users of light rail and bus transit services have a variety of different needs for infrastructure and support, but one common need on which their success depends is convenient, safe access to other modes of transportation.

Recognizing this, Bi-State provides bus service and park-and-ride lots at several of its Metrolink rail stations. The failed Kansas City light rail proposal would have provided 2,500 parking spaces at park-and-ride stations

Similarly, the success of inter-city passenger rail or bus service critically depends on connections with other modes of transportation. It is important that passenger rail and intercity bus service have easy highway access with sufficient parking spaces and be adjacent to local public transportation, including public transportation connections to major airports. Some current bus and rail terminals in Missouri fail to meet these criteria. However, the proposed MWRRRI rail

network would be complemented by a feeder bus system serving communities near station locations.

An example of the integration of transportation strategy with city planning is Portland, Oregon where 40 percent of downtown work trips arrive on transit. Transit has become the mode of choice for 64 percent of Tri-Met's light rail riders, meaning they have a car available for the trip.⁵⁷

Generally, when one alternative mode is strongly established it helps the success of other modes. For example, in cities where light rail transit has been built, the availability of light rail has spurred pedestrian-friendly development, especially near light rail stations. Because rail attracts more riders than buses, it can, from the perspective of many businesses, function as an extremely effective customer delivery system. More pedestrian traffic means more opportunities for commercial development as well as multi-family housing near the rail stations – and a development pattern with less space set aside for the economic dead weight of parking.

For example, at St. Louis Metrolink's Busch Stadium station, Bi-State is planning to convert an area of historic warehouses into a mix of offices, retail shops, housing and hotels. A local developer is planning to transform the old Manhattan Coffee warehouse immediately adjacent to the station into a restaurant/retail complex. The new federal courthouse a few blocks away may spur additional development.

Nationally, many communities have responded to congestion by implementing new approaches to transportation planning, such as better coordinating issues of urban design and geographic dispersion with transportation requirements; increasing the availability of high quality transit service; creating redundancy, resiliency and connectivity within their road networks; and ensuring connectivity between pedestrian, bike, transit and road facilities. In short, they are coupling a multi-modal approach to transportation with supportive development patterns to create a variety of transportation options.⁵⁸

Travel Needs and Planning

As was noted earlier, continually increasing VMT has led to continually increasing CO₂ emissions from Missouri highway travel. Reducing VMT, or at least dampening the growth of VMT, prevents CO₂ emissions that would otherwise occur.

Actions to reduce VMT can be a significant component of “harmonized” policies for environmental protection because reductions in VMT are likely to reduce both CO₂ emissions and transportation-related emissions of criteria pollutants. Highway travel is the source of 58 percent of carbon monoxide (CO) emissions, 38 percent of NO_x emissions and 32 percent of VOC emissions in Missouri.

⁵⁷ Arrington, G.B., *Beyond the Field of Dreams Light Rail and Growth Management in Portland*, 1998. Arrington is the Director of Strategic Planning for Portland's Tri-Met system.

⁵⁸ For examples see <http://www.smartgrowth.org/about/principles/principles.asp?prin=8>.

Reductions in VMT also result in reduced traffic congestion. Reflecting national trends,⁵⁹ virtually all Missouri motorists using the state highway and bridge system must deal with roadway congestion. Beyond the personal inconvenience that congestion imposes, it has social costs. MoDOT estimates the societal costs for delays associated with congestion in Missouri at almost \$400 million per year, based on traffic delays and adverse effect on industry and commerce.⁶⁰ The start-and-stop travel that is often associated with traffic congestion also tends to increase the level of travel-related criteria pollutants.

Finally, reductions in VMT may help control the inflationary impact that continually increasing VMT imposes on costs and other requirements for maintaining an adequate road and bridge system. MoDOT has estimated that the state must expend about \$12 billion for state road and bridge repair and maintenance over the next few years. This total includes more than \$7.1 billion in expenditures required to stop the rate of deterioration on NHS and major arterial roads and bridges and maintain them in acceptable condition. An additional \$4.8 billion would be required to restore and maintain other state roads and bridges.⁶¹

The need for these repairs is driven in part by increasing highway VMT. VMT on the state highway and bridge system has more than doubled since 1973. The continuing increase in VMT has had an overall negative impact on the condition of the state highway and bridge system. According to MoDOT data, the miles of pavement rated good has decreased each year since 1995 on the NHS and remaining arterials.⁶²

Travel planning, including choices about travel needs and mode of travel, is the principal discretionary factor affecting vehicle miles traveled. Planning can take place at a personal, institutional or societal level.

Trip Planning at the Personal Level

Highway VMT is affected by travelers' decisions about their need for travel, their choices from available travel modes and their efforts at efficient trip planning.

A simple example of efficient trip planning is combining multiple errands into one trip. The traveler saves time, money, vehicle wear and fuel. Besides reducing the total distance traveled, trip planning avoids multiple starts. Several short trips taken from a cold start can use twice as much fuel as a longer multi-purpose trip covering the same distance when the engine is warm. Trip planning ensures that traveling is done when the engine is warmed-up and efficient.

⁵⁹ Nationally, 65 percent of travel occurred in uncongested conditions in 1982. By 1997 only 36 percent of peak travel did so. Furthermore, road congestion, once considered an urban phenomenon, now affects rural roads as well. The 1999 Status of the Nation's Highways, Bridges and Transit: Conditions and Performance indicates that volume of traffic per lane has increased faster on rural highways than in urban areas.

⁶⁰ MoDOT, *ibid*, p. 17

⁶¹ Missouri Department of Transportation, *Long Range Transportation Direction*, 2001, pp.13-14. Acceptable condition is defined as 80 percent of desired condition for the NHS and 75 percent of desired condition for the arterials. As described earlier, the NHS portion of the state highway system includes about 13 percent of total mileage and carries 62 percent of total state highway traffic. Remaining arterials include 15 percent of total mileage and carry about 20 percent of state highway traffic.

⁶² MoDOT, *Highways and Bridges*, draft Long Range Transportation Plan, unpublished, pp. 1-2.

Transportation Needs Planning at the Institutional Level

At an institutional level, effective travel planning is a necessity of efficient business or agency management. Policies can be set to assure that travel is justified by business need. Fleet managers routinely reduce fleet costs and fuel use through efficient dispatch and routing of fleet vehicles.

Institutions also have opportunities to substitute telecommunications technology for physical travel. Two uses of telecommunications technology that have received widespread attention are teleconferencing and telecommuting. Appropriately used, these technologies can benefit the institution while also avoiding energy use and CO₂ emissions that would otherwise occur.

Telecommuting

Telecommuting involves substitutions of telecommunications services – usually, computer – for commuting to a central workplace. Workers may be stationed at home or at a satellite office.

The primary candidates for telecommuting appear to be workers whose main function is to create, distribute or use information. These include white-collar workers with managerial and professional specialties, or workers in sales and clerical jobs. Because over 50 percent of U.S. jobs fit this description, theoretically a large number of jobs are candidates for telecommuting.

Although telecommuting reduces GHG emissions from travel by eliminating work trips, there may be “take back” effects such as the following:

- Extensive telecommuting could stimulate sprawl because workers would have less incentive to locate close to a central office.
- Some research indicates that non-commuting trips by telecommuters increase as work trips decrease.

A 1994 U.S. DOE study estimated the direct and indirect impact on total motor fuel use of enlisting 30 million U.S. workers in a telecommuting program. The study estimated that direct impact would be avoidance of nearly 70 billion miles of commute trips per year, but that increased urban sprawl and increased non-commuting travel would offset nearly half of the direct impact.⁶³

The success of telecommuting probably depends in part on the corporate and managerial climate of the employer and perhaps on the personality of the employee. Some researchers have identified a backlash effect among workers who perceive that telecommuting creates social isolation and lack of communication, loss of benefits and career advancement and increased stress from mixing work and home life.

Teleconferencing

Continuing advances in telecommunications reduces the need for some face-to-face meetings. Teleconferencing options are available that allow interactive and effective meetings between

⁶³ Greene, D.L., A. Hillsman and J.M. Niles, 1994, *Energy, Emissions and Social Consequences of Telecommuting*, U.S. DOE, 1994. Telecommuting behavior studies by researchers at the Institute of Transportation Studies at University of California-Davis appear to confirm that “take back” effects are likely to be significant.

individuals or groups at separate sites to take place at a fairly reasonable cost, using local downlink facilities or other digital technologies. Depending on the meeting, teleconferencing could substitute for local or long-distance travel.

Well-established variations of teleconferencing include:

- Audio-only teleconferencing using telephone lines and teleconferencing “bridges,” which permit participants at over one hundred sites to interact.
- Audio-plus teleconferencing, which supplements audio technology with handout materials, overheads and videos.
- Two-way video teleconferencing, which allows participants at remote sites to both see and hear each other.
- One-way video / two- way audio teleconferencing, in which a video image from a single site is transmitted but two-way audio interaction is possible from several distinct locations.

In many instances the need for travel can be significantly reduced through the use of these technologies. However, it should be recognized that physical meetings may offer essential benefits that cannot be captured by teleconferencing. Examples are opportunities to establish relationships with other agency staff and stakeholders, to inspect geographic and other characteristics of an area where a project is to take place, to inspect sites of existing projects and to work with maps, document archives and other paper documents that are not readily shared through a teleconferencing medium.

Transportation Needs Planning at the Societal Level

At a societal level, transportation needs are affected by societal choices about the geographic distribution of community and economic activities and institutions. Research supports the common sense proposal that fuel use increases as geographic dispersion increases, simply because people have farther to travel to meet their needs. A survey of 32 major cities around the world found that the residents of American cities consume nearly twice as much gasoline per capita as Australians, nearly four times as much as residents of the more compact European cities and ten times that of residents living in very compact Asian cities.⁶⁴

Since 1982, the U.S. population has grown 20 percent, but the time spent by commuters in traffic has grown 236 percent. One of many factors driving this statistic is an increase in the distance between home and workplace, resulting in routinely long commuter trips and congestion of roadways by commuter traffic. Dispersal of residences, workplaces and shopping areas also increases the expense and difficulty of providing adequate public transportation coverage to communities.

The Brookings Institute Center on Urban and Metropolitan Policy has undertaken two projects to analyze, assess and report on growth trends and policies in Missouri and Greater Kansas City. The projects are intended to provide state and local business, civic and political leaders with a larger understanding of the issues and trends affecting the health of the state and its regions, and arm them with a menu of policy options. The projects incorporate a series of meetings with state

⁶⁴ Cited in STAPPA/ALAPCO, p. 110.

and area stakeholders as valuable advisors and will conclude with an array of briefings for state and local decision-makers, business and civic leaders and other constituencies.

Brookings' statewide analysis will document key demographic, economic, social and land development trends across Missouri and in key metropolitan areas including the Kansas City, St. Louis, Columbia, Springfield, Joplin and St. Joseph areas. The statewide analysis will examine the implications of these growth trends for central cities, first ring and outer suburban areas. It will particularly focus on the changing nature of the economy in the state's large metropolitan areas and assess the ability of these places to compete for growth sectors like biotechnology. The statewide analysis will also examine the health of the rural areas of the state and provide an agenda for rural economic development. A concluding report will recommend policy options to curb sprawl, enhance urban competitiveness, lessen fiscal disparities between jurisdictions and enhance access to employment opportunities for all state residents.

Brookings' second project is intended to provide Kansas City political leaders, business and civic community, citizen groups and residents with basic knowledge and understanding of growth trends in the Kansas City metropolitan area. The concluding report will set out an agenda to build strong, vibrant neighborhoods that are home to good schools, good job opportunities and quality services and are linked to other residential and employment centers in the larger economy.

Technical Options to Reduce GHG Emissions from Freight Transportation in Missouri

Because Missouri is centrally located with respect to national and regional trucking, train and barge routes, it is the focus for very substantial interstate movements of freight originating from, destined for or simply passing through the state.

During the 1990s, the nation's economic expansion and Missouri's central location fed strong growth in freight cargo movements in Missouri by truck, train and air. Because diesel engines power 94 percent of all freight movement by trucks, trains, boats and barges, one consequence was increased diesel fuel use accompanied by increasing CO₂ emissions. CO₂ emissions from diesel fuel use increased at an annual average growth rate of 6.8 percent. A portion of the state's large increases in jet fuel use and emissions, particularly at Kansas City International (KCI) airport, is also attributable to growth in air freight movements.

As previously noted, it is likely that interstate freight movements by commercial transportation companies and independent truckers located outside Missouri contributed to some of these increases.

Freight Transportation Infrastructure and Use

Freight movement in Missouri is characterized by a great diversity of transportation modes. In particular, the St. Louis and Kansas City metropolitan regions possess sophisticated freight and goods movement systems, including extensive highway networks, railroads, pipelines, cargo-oriented airports, river ports and numerous modal and intermodal terminals.

Vehicles and vehicle parts manufactured in Missouri generate the primary outbound air, rail and truck cargo. Important petroleum and natural gas pipelines traverse or terminate in Missouri.

Highway freight: Missouri is home to a number of important interstate highways including I-70, a major east-west corridor. Freight movement occurs predominantly on state-maintained roadways including the NHS, and other heavily traveled rural and urban roads.

On a daily basis, according to the American Trucking Association, trucks move an average of 333,000 tons of outbound and 400,000 tons of inbound freight in Missouri.⁶⁵ Diverse commodities are moved including clothing, electronics, farm supplies and household necessities.

Kansas City is the leading origin and destination for Missouri regional truck traffic. According to a 1995 report, the Kansas City area had about 8,000 establishments in the business of trucking and warehousing, including 30 firms with at least 100 employees and a handful with over 500 employees.

Rail freight: Freight rail transport is a significant component of Missouri's transportation system. Kansas City has the second largest and St. Louis the third largest rail hub in the United States.

Rail moves approximately 40 percent of the freight leaving and 60 percent of the freight entering Missouri. Coal from Wyoming's Powder Basin region is the leading commodity arriving in Missouri by rail.

Class I carriers, which by definition have annual gross revenues of more than \$250 million, operate about 81 percent of the total main line track in Missouri. Over the past 30 years, mergers have completely changed the landscape of the rail industry in Missouri and the United States. While many Class I carriers existed in the past, only a few currently operate. The general trend is for continued consolidation into more efficient corridors.

Missouri's freight rail system consists of about 4,400 main line miles of track. However, a large amount of rail traffic travels on a small number of lines. These corridors have also received most of the Class I investment over the past 10 years.

Airfreight: Missouri's two busiest commercial passenger airports are Kansas City International (KCI) and Lambert-St. Louis International (Lambert). During the 1990s, airfreight tonnage handled at KCI grew rapidly (nearly a 10 percent annual increase), fueled in part by manufacturers' increasing emphasis on just-in-time delivery systems. Growth has exceeded the national average and is likely to continue.

Airfreight tonnage at Lambert has grown only 3.6 percent during this period. Lambert does not pursue airfreight aggressively because most freight shipments occur at night and the airport has several noise-sensitive residential developments surrounding the airport.

Other air traffic in the state is largely driven by economic and business conditions. Robust economic growth will lead to robust growth in air traffic.

Pipelines: An extensive system of pipelines carries natural gas, oil, petroleum products and other gaseous and liquid products into and through Missouri.

Missouri has no commercially operating freight pipelines – pipelines that carry solid products such as grains, minerals and wastes. However, the nation's leading research center on freight pipelines is based at University of Missouri-Columbia.

⁶⁵ <http://www.truckline.com/safetynet/sharetheroad/missouri.html>

Commercial waterways and ports: Missouri's two most important commercial waterways are the Mississippi and Missouri Rivers. The leading commodities shipped from Missouri by barge are cement and grain; the leading commodities arriving in Missouri by barge are coal and petroleum refining products.

Total tonnage moved along the Mississippi River increased from 298.87 million tons in 1989 to 323.4 million tons in 1998, a modest growth rate of 0.8 percent per year. Downbound traffic during this same 10-year period experienced a 0.3 percent per year growth; upbound traffic grew at a rate of 1.6 percent per year. Barge movement in 1999, by river segment, was as follows:

Iowa line to St. Louis	180 miles	85.7 million tons	15.4 billion ton-miles
St. Louis to Cairo	180 miles	124.7 million tons	22.4 billion ton-miles
Cairo to Arkansas	130 miles	204.9 million tons	26.6 billion ton-miles

Much less barge freight moves on the Missouri River. Total movement increased from 5.35 million tons in 1989 to 8.34 million tons in 1998, a growth rate of 4.5 percent per year. Non-metal commodities account for 80 percent of the goods moved. Water-borne freight moves between March and November.

Areas of Technical Opportunity

Freight transportation has different characteristics from human travel. Moving people requires flexibility, convenience and speed. Transporting freight requires cost-effectiveness, on-time delivery and security in transit. A commercial carrier operating in any mode – highway, rail, water, air or pipeline – must meet these requirements in order to remain in business.

Commercial carriers must make large capital investments in some cases, such as rail owning and operating the infrastructure or vehicles, and are strongly motivated by profit considerations to maximize operational efficiency. Under these circumstances, there may be less opportunity or need for public involvement in attaining energy efficiency.

For example, several private-sector carriers in Missouri are at the national forefront in the deployment and use of fleet management and freight management systems. These systems result in lower operational costs, improved customer satisfaction and greater efficiency.

Publicly sponsored research and development (R&D) can create opportunities to enhance the efficiency of various freight transportation modes. In many cases, R&D is most effectively sponsored by federal agencies such as U.S. DOE or U.S. DOT. These agencies have long funded and sponsored R&D to improve the fuel efficiency of trucks and otherwise enhance operational efficiency in privately owned and operated freight transportation modes such as truck and rail. Similar R&D opportunities exist to advance the use of freight pipelines.

Opportunities also may exist for public-private partnerships to improve vehicle or infrastructure efficiency. However, as with R&D, these are often better approached at a federal or regional level rather than a state level, because the industries involved are typically organized at a regional or national level and freight movements typically have an interstate character.

Advanced Highway Freight Technology

Highway freight transportation in Missouri, as nationally, is dominated by diesel-powered trucks. Nationally, heavy-duty diesel trucks account for about 90 percent of total highway freight VMT and nearly all long-haul transport.

Opportunities to promote advanced freight diesel technologies do exist but they are already being pursued at a national level. The U.S. DOE's OTT pursues projects oriented toward heavy diesel vehicles with the goal of achieving 55 percent fuel efficiency and reducing emissions from highway freight transportation. Among the freight technology projects pursued by OTT are fuels formulation, blending, sensing and control strategies to enable greater use of non-petroleum fuels such as biodiesel. However, the average life of a heavy truck is 29 years, nearly double that for light vehicles. The process of replacing old with new heavy truck technology is correspondingly slower.⁶⁶

The state does have opportunities to enhance the freight movement efficiency of heavy trucks through advanced highway management practices. Commercial truck operators will benefit along with highway travelers from incident management and traveler information systems being implemented by MoDOT and other transportation authorities. In addition, MoDOT has begun to implement advanced commercial vehicle operations systems such as electronic clearance and weigh-in-motion systems intended to reduce commercial truck delays at weigh stations.

In April, 2002, the Missouri Transportation Commission approved the use of PrePass technology to allow commercial vehicles to bypass weigh stations at 19 locations in the state. The 19 weigh stations monitor nearly all truck traffic entering the state and typically inspect more than 300,000 commercial vehicles each per year. Sensors at the weigh-station will verify whether each participating vehicle has a satisfactory safety rating and is current on registration fees, fuel taxes and insurance. A small transponder attached to the driver's windshield indicates whether the driver may pass or is required to stop. The system may be in place by the end of 2002.

Electronic clearance and weigh-in-motion systems reduce commercial fuel use and increase operating efficiency. A study of trips on I-75 from Florida to Ontario, Canada indicated fuel savings of 0.05 to 0.18 gallons per avoided stop. There might also be a modest improvement in the fuel efficiency of other highway vehicles due to a reduction in traffic accidents and delays that routinely result from weigh station spill-over onto the mainline of traffic.

Advanced Freight Pipelines

Pipelines have long been the method of choice for transporting liquid and gaseous products. Freight pipelines promise to offer an inexpensive, fast, safe, reliable and energy-efficient method for transporting solid items such as grains, minerals and wastes. By separating freight transportation from human movement, freight pipelines could increase the efficiency and safety of both. Preliminary estimates indicate that the energy efficiency of freight movement in advanced-technology freight pipelines, measured in Btu per ton-mile, should equal or exceed the efficiency achieved by freight rail.

⁶⁶ Transportation Energy Data Book, Tables 6.11 and 6.15.

Intermodal Coordination of Freight Movement

Improving connections and transfers within and between the different freight modes of truck, rail, barge and air is a vital component of a cost-effective transportation system. Businesses like Federal Express and UPS whose profit depends on economic efficiency and on-time performance have long realized that the most reliable way to move a product between points is to utilize a variety of different transportation modes.

There have been a number of public-private intermodal planning efforts in Missouri over the past ten years. For example, in 1992 MoDOT studied the feasibility of developing an intermodal center in Columbia that incorporated a public port, warehousing and intermodal connections between trucking, rail and water transportation.

In the mid-1990s, regional plans for intermodal development in the St. Louis and Kansas City areas were developed in response to federal mandates established by the intermodal Surface Transportation Efficiency Act (ISTEA). Participants in these planning efforts included MoDOT, private-sector representatives from the various transportation industries and the regional planning organizations, the East-West Gateway Coordinating Council (EWGCC) in St. Louis and the Mid-America Regional Council (MARC) in Kansas City.

These regional plans defined goals and objectives for intermodal development and benefits to be gained from each, identified infrastructure improvements for each of the various modes, established intermodal efficiency indicators and most importantly, identified a number of projects that could improve the energy efficiency of the regions' freight transportation systems.⁶⁷

An example of effective intermodal planning by Missouri's rail carriers is the Kansas City flyover (bridge). Prior to construction of the flyover, the junction of Union Pacific and Burlington Northern rail lines in Kansas City was highly congested. The construction of a mile-long flyover to separate the rail grades, with a bonding initiative underwritten by MoDOT, has significantly improved the efficiency of rail movement at this junction.

Public port authorities offer a natural focus for intermodal planning, because any business choosing to locate at a public port is likely to require access to two modes of transportation. Public port authorities are political subdivisions of the state, authorized pursuant to Chapter 68 RSMo. Of 202 port facilities in Missouri, fourteen are considered public ports and nine currently function as private ports. Private ports move more freight than public ports, but are generally dedicated to a specific commodity and are not used for general freight.

The Southeast Missouri (SEMO) Port Authority offers an excellent example of effective intermodal planning tailored to industrial needs. The port authority works individually with industrial firms locating at the SEMO port to provide needed access to barge rail, truck or pipeline transport as well as assure access to electric and water utilities. The port is served by three railroads, four major highways (I-55, I-57, I-24 and US 60), and three pipelines. The SEMO Port Railroad, a subsidiary of the port authority, is a common carrier switching railroad

⁶⁷ EWG, <http://www.ewgateway.org/html/wphtml/frtpapr.htm>, 1997; MARC, *Intermodal Freight Strategies Study*, August 1995

whose seven miles of track include a lead track to the Port's harbor industrial area on the Mississippi River.⁶⁸

Outside Missouri's public port authorities, successful implementation of intermodal planning has been difficult due to the competitive nature of commercial freight carriers and differences in the planning timeframes assumed by carriers and planning agencies.⁶⁹

However, there is little question that additional opportunities for greater intermodal efficiency exist. For example, an intermodal rail yard could improve the efficiency of rail movement in St. Louis. This was proposed by the St. Louis intermodal plan but has not yet been implemented.

The existing system, with many small railroad terminals located throughout the St. Louis Region, requires loads to be transferred between small terminals on local roads. For example, an estimated 50,000 trucks annually use Illinois Route 3 to transfer goods from Union Pacific's terminal in Dupon, Illinois to the Conrail terminal in Fairview Heights, Illinois.

The proposed intermodal terminal, by allowing transfer of loads at one centralized rail yard, would relieve congestion on the roadway system, reduce the potential for accidents on local roads and improve the efficiency and transfer times for rail shipments.

Policy Options to Reduce Greenhouse Gas Emissions from Missouri's Transportation Sector

This policy review focuses on options to reduce CO₂ emissions from highway vehicles burning motor gasoline or diesel fuel. Reasons for this focus are as follows:

- As discussed in the technical options section of this chapter, almost all GHG emissions from Missouri's transportation sector are in the form of CO₂ from fossil fuel use. Any plan to reduce CO₂ emissions must include a transportation component because this sector accounts for about a third of Missouri's total CO₂ emissions from fossil fuel use, second only to the utility sector. The appropriate forum for controlling other greenhouse gases from the transportation sector is through federal clean air requirements and related federal programs such as EPA's plan to phase in low-sulfur diesel fuel use for highway freight transportation.⁷⁰
- Emissions from highway travel account for about 85 percent of the transportation sector's CO₂ emissions in Missouri. The remaining 15 percent derive from many different modes of travel spanning a wide range of activities including boats, airplanes, jets and railroads. The largest of these "other" contributors, air travel, is not easily dealt with on a state level due to its interstate nature.⁷¹

⁶⁸ Personal communication, Daniel Overbey, SEMO Port Executive Director, April 11, 2002; SEMO Port Authority, Miscellaneous publication received April 15, 2000

⁶⁹ Personal communication, Daryl Fields, MARC, April 11, 2002

⁷⁰ STAPPA/ALAPCO p. 115 discusses the impact of low sulfur diesel on other GHG emissions.

⁷¹ EPA's guidance document for state GHG plans recommends omitting policy options for air travel due to the interstate nature of air travel and emissions.

Policies to reduce greenhouse gas emissions from highway vehicles can be classified into the following three categories:

- Policies whose objective is to increase vehicle efficiency, resulting in less fuel use and lower GHG emissions per mile traveled (vehicle efficiency).
- Policies whose objective is to shift vehicle owners from conventional to alternative and renewable fuel use, which may result in lower GHG and other emissions per Btu of fuel use.
- Policies whose general objective is to reduce the use of carbon-intensive transportation modes such as low-occupancy highway vehicles. There is great diversity of specific objectives in this category, for example:
 - Reducing the need to travel.
 - Reducing the frequency or distance of trips.
 - Shifting transportation from carbon-intensive modes such as low-occupancy highway vehicle modes to other modes such as high-occupancy vehicles, rail, transit or non-motorized pedestrian and bicycle travel.

MoDOT has responsibilities and resources that are key to successful implementation of policy options presented here. MoDOT carries out comprehensive long-range transportation planning for the state in coordination with regional and local transportation planning authorities.

Recently, MoDOT completed a comprehensive statewide planning effort that drew extensively on public input and sets the direction for development of the state's transportation infrastructure. The plan, published as Missouri's Long-Range Transportation Direction (LRTD), commits MoDOT to identify and meet needs for development of all modes of transportation in Missouri. At the same time, MoDOT commits itself to providing a well-maintained and well-managed state highway system, which is a prerequisite to achieving highway vehicle efficiency.

In the course of developing the LRTD, it became clear that there was a large gap between the state's transportation needs and the funding available to meet those needs. In order to implement policies described in this chapter, as well as meet other pressing transportation needs, these funding issues need to be solved.

At present, MoDOT relies heavily on funding from Missouri's fuel sales tax. A constitutional amendment passed in 1979 provides that half of Missouri's fuel sales tax goes to finance road and bridge construction. Of this half, 74 percent goes to MoDOT, 15 percent to the cities and 10 percent to the counties. The remaining 1 percent goes for planning of other transportation modes.

An unintended consequence of some policy options presented here might be to reduce fuel use and therefore reduce funds collected from the fuel tax. Therefore, alternative or supplementary sources of funding for MoDOT and other transportation authorities in the state should be considered.

This review of action options can be divided further into two groups – (1) options that focus on reducing transportation-related CO₂ emissions from the public sector, including the management of state agency fleets and travel for state-related business; and (2) those that focus on the private sector, including personal and business travel as well as freight transportation.

Actions directed at reducing emissions from the state fleet and state business-related travel directly affect total emissions. Equally important, they provide credibility to the state's efforts to reduce emissions from the private sector.

- State agencies are significant users of transportation fuels, accounting for more than 15 million gallons of gasoline, diesel and other transportation fuel use in fiscal year 2001. Like other transportation users, state agencies could reduce their direct contribution to total CO₂ emissions through actions that favor efficient vehicles and alternative fuel use in the state fleet and a shift from carbon-intensive travel modes for state travel. As described in the technical section of this chapter, many direct economic and environmental benefits in addition to CO₂ reduction would flow from these decisions.
- CO₂ emissions from private sector highway travel far exceed those from the public sector. The level of greenhouse gas emissions from the private sector is determined by countless transportation decisions by Missouri businesses and citizens. The Statewide Energy Study recommends that state and local governments should become “visible leaders in promoting efficiency in the transportation sector.” Similarly, the Missouri Energy Policy Task Force (MEPTF) recommends that by its management of vehicles as well as buildings, the state of Missouri should “lead the way” by setting “an example for its citizens to follow.”⁷² In most instances, state efforts to affect transportation-related CO₂ emissions from the private sector must rely on information, persuasion and collaboration – approaches that require credibility to be effective.

Enhance and Coordinate Efforts to Inform Missouri Citizens Regarding the Benefits of Efficiency, Alternative and Renewable Fuel Use and Multi-Modal Flexibility in Missouri's Transportation System

As recommended by the Energy Futures Coalition (EFC), a statewide network including the state and other governments, educational and not-for-profit organizations should be developed to educate Missouri citizens regarding transportation options and costs in order to make informed daily and long-term choices. This effort should include information about vehicle efficiency, opportunities for shifting toward alternative and renewable fuels and the different modes of transportation, the benefits each mode offers communities and how they all interconnect to form a transportation system.

The EFC report documents current transportation information activities and suggests opportunities for improving their coordination and efficacy.

Promote the Fuel Efficiency of Highway Vehicles in Missouri

Implement Fuel Efficiency Measures Included in Missouri Statutes

Missouri's State Fleet Efficiency and Alternative Fuels legislation (RSMo 414.400-414.417), passed in 1991 and revised in 1999, requires state agencies to develop and implement plans to acquire and maintain fuel-efficient vehicle fleets, promote efficient trip planning and state

⁷² MEPTF, *Final Report*, 2001, p. 16

vehicle use, and reduce single-occupant vehicle (SOV) trips by state employees through strategies such as carpooling and vanpooling.

The following policy options are drawn from the *Model Plan for the Fuel Conservation for State Vehicles Program* published as guidance for the state agency plans.

Implement Procurement Policies Designed to Increase the Energy Efficiency of State Vehicle Fleets

The greatest opportunity to improve the overall fuel efficiency of agency fleets is through procurement, when older and less fuel-efficient vehicles are replaced.

State agencies should purchase only vehicles that meet or exceed federal Corporate Average Fuel Economy (CAFÉ) standards and increase the proportion of fuel-efficient vehicles purchased.

Increase and Maintain Efficient Fuel Usage Within the Fleet Through Enhanced Fleet Management and Maintenance Procedures

Agency strategies to implement this recommendation should include:

- Assigning smaller and more fuel-efficient vehicles first if travel needs can be met with a smaller vehicle.
- Developing energy-efficient routes and schedules for routine trips.
- Instituting a formal maintenance program to maintain maximum fuel-efficiency ratings of all fleet vehicles, including routine assessments of tire pressure and wear on all vehicles.

Consider Increasing the Efficiency of Fleet Vehicles that are Exempt from the Requirements of the State Fleet Efficiency and Alternative Fuels Law

About two-thirds of vehicles operated by state agencies are exempt from the requirements of this law, and these exempt vehicles use about 85 percent of total transportation fuel consumed by state agencies. Agencies should develop management and maintenance plans and policies to enhance fuel efficiency in the “exempt” portion of the fleet and should review opportunities to incorporate fuel economy as a factor in vehicle procurement.

Require State Agencies to Report on Compliance with Missouri's State Fleet and Efficiency and Alternative Fuels Law in Their Annual Budget Requests

The annual budget process provides a highly visible forum for planning and monitoring progress on state agency goals, objectives and priorities. Acknowledging this, the Missouri Energy Policy Task Force recommended that the Governor require each agency to report on its current compliance and its plans to achieve compliance in annual agency budget proposals.

Encourage Private Sector Vehicle Owners to Operate and Maintain Their Vehicles for Optimal Fuel Efficiency

An assessment of public information and training on vehicle maintenance in Missouri should include a review of driver education curricula in Missouri secondary schools, public and private training and certification programs for automobile mechanics, and general information directed to vehicle owners and operators.

While the primary purpose of the Enhanced Inspection and Maintenance (I/M) program in St. Louis is to reduce emissions of criteria pollutants and improve air quality, it has the additional benefit of increasing vehicle efficiency. The state could build on this benefit for motorists whose vehicles are inspected, by documenting this benefit, explaining it to St. Louis motorists whose vehicles are inspected and assessing opportunities to tie the St. Louis I/M program to other efforts to provide information, training or incentives focused on preventive maintenance.

Consider Establishing a Revenue-Neutral System of Incentives such as Feebates or Graduated Registration Fees to Encourage Missourians to Purchase Fuel-Efficient Vehicles

A number of states including Maryland, California, Massachusetts, Arizona, New York, South Dakota, Rhode Island and Iowa have considered implementing a revenue-neutral “feebate” system, that would place an up-front surcharge on vehicles whose fuel efficiency falls below a certain standard and provide a commensurate rebate for vehicles significantly more efficient than the current average.⁷³

In general, state proposals have differed significantly from the 1978 federal “gas-guzzler tax.” Some features of the federal program are as follows:

- The federal program places a surcharge on vehicles whose fuel efficiency falls below a certain standard. However, the federal program does not include a rebate for efficient vehicles. Thus, it is not revenue-neutral and it provides no incentive to purchase highly efficient vehicles.
- The federal definition of “gas-guzzler” (cars falling below 22.5 mpg) has not been modified since 1986 despite significant developments in fuel economy technologies since that time and the greatly increased popularity of sport utility vehicles (SUVs). “Light trucks” including SUVs are exempt from the federal tax.

Any effort to implement a state feebate program will require careful legal consideration of its relationship to the federal program. In 1992, Maryland became the first state in the nation to enact a feebate proposal. Maryland’s law would have increased or decreased the 5 percent motor vehicle titling tax depending on vehicle fuel efficiency. However, the Maryland law called for the seller to display the excise rate for a particular vehicle with a colored sticker on the vehicle window explaining the relationship between the state’s excise tax and the vehicle’s fuel economy. The National Highway Traffic Safety Administration blocked implementation of the Maryland law, arguing that the labeling provision in the law violated federal preemption of automotive fuel economy regulations.

⁷³ Personal communication, Terese Langer, American Council on an Energy Efficient Economy, February 15, 2001.

Furthermore, any effort to implement a state feebate program should include careful consideration of its possible impact on low-income motorists. For example, purchasers of used vehicles might be permitted to opt out of the system of feebates or graduated registration fees.

Consider Action at the Federal Level to Reclassify Sport Utility Vehicles (SUVs) as Passenger Vehicles and Update Federal Corporate Average Fuel Economy (CAFE) Fuel Efficiency Requirements for These and Other Vehicles

As discussed in the section on technical options, an increase in CAFE standards would have a number of benefits as well as costs. One likely benefit would be a reduction in CO₂ emissions. Support of enhanced CAFE standards was recommended by the Missouri General Assembly's Special Committee on Fuel Prices in its final report.

Promote Alternative and Renewable Fuel Use in Highway Vehicles in Missouri

This section lists a number of options to promote the use of AFVs and alternative fuels and the infrastructure necessary to support their use.

The options listed do not include major state financial incentives for private sector purchases of AFVs. While these might be considered in the future, at this time state funds for new initiatives are scarce and the financial impact of state AFV incentives is difficult to predict.⁷⁴ Incentives such as tax credits would be more readily provided at the federal level. Recent federal legislative proposals would provide tax credits for purchases of fuel cell and hybrid vehicles.

Implement AFV Purchase Requirements Included in Missouri Statutes

Missouri legislation passed in 1991 (RSMo 414.400-414.417) and revised in 1999 requires state agencies to meet a series of targets for including AFVs in their state fleets. In general, the statute requires that a targeted percentage of new vehicle acquisitions should be capable of using alternative fuels. The targets are 10 percent by mid-1996, 30 percent by mid-1998 and 50 percent after mid-2000. The law's requirements are described in greater detail in the *Missouri State Fleet Efficiency and Alternative Fuel Program Annual Report*. According to the report, many state agencies have not yet met the law's requirements.

Fully Implement the Requirements of the Law as Written

State agencies should meet the requirements of state law for incorporating AFVs into state fleets and should adopt recommendations by the Energy Futures Coalition and the Missouri Energy Policy Task Force for assuring that this law is fully implemented.

Monitor the Adequacy of the Current 10 Percent Incremental Cost Allowance for Purchasing AFVs

The incremental cost allowance is a differential that permits state agencies to purchase AFVs that cost more than comparable conventionally-fueled vehicles.

⁷⁴ Morrison, Melissa, *Arizona's Alternative Fuel Incentives Backfire*, *Washington Post*, December 11, 2000

The Energy Futures Coalition recommended increasing the allowance to 12 percent. In 1999, the Missouri legislature increased the incremental cost allowance from 5 to 10 percent. Vehicles to be used in St. Louis (a clean air non-attainment area) and Kansas City (a clean air maintenance area) may exceed the cost of a gasoline-powered vehicle by as much as 17 percent.

Agency AFV purchases should be monitored to determine whether additional changes in state procurement requirements and procedures are needed to enable agencies to meet targets for agency AFV purchases.

Implement Alternative and Renewable Fuel Use Requirements Included in Missouri Statutes

Missouri legislation passed in 1991 (RSMo 414.400-414.417) and revised in 1999 includes requirements for state agency use of alternative and renewable fuel in the AFVs in their fleets. State agencies should meet the requirements of this law. The law requires that by July 2001, 30 percent of total fuel use in state AFVs should be alternative fuel. The Missouri Energy Policy Task Force recommended that this requirement be increased from 30 to 50 percent alternative fuel use.

This cannot be accomplished by state agencies acting alone. The state must identify and actively promote opportunities for collaboration with the federal government, municipal government and private sector fleet managers and fuel suppliers.

- As the EFC report states, Missouri should “encourage the federal government to implement and support the alternative fuel use requirements of the Energy Policy Act of 1992. (EPAct),” including federal funding incentives authorized by EPAct to accelerate the use of alternative fuel vehicles by state government.
- Infrastructure development is key to achieving the goals and requirements of current state law and as is further elaborated in the next section, can only be accomplished through collaboration with other government and private sector stakeholders in programs such as the federally sponsored Clean Cities program.

In the mid-1990s, state agencies were in compliance with the 30 percent alternative fuel use requirement. In 1996, alternative fuel use in state AFVs was 45 percent of total fuel use. However, since 1996, alternative fuel use in state AFVs has decreased to well below compliance level. According to preliminary data, alternative fuel use in state AFVs was only about 12 percent of total use in 2001.

A key factor in this change is that between 1996 and 2001, in order to comply with AFV purchase requirements, state agencies rapidly added E85 vehicles while retiring propane and CNG vehicles. State-owned E85 vehicles can run on gasoline obtained at any retail station but have access to only a few stations that supply E85 fuel. By contrast, state-owned propane and CNG vehicles often have dedicated fuel sources.

Missouri State Agencies Should Fuel Conventional Vehicles with Ethanol and Biodiesel Fuel Mixes Where it is Feasible to do so; School Districts and Local Governments in Missouri Could also Develop Policies Favoring Biofuel Use

As previously noted, about 85 percent of total transportation fuel use by state agencies is by vehicles that are exempt from the requirements of Missouri's State Fleet Efficiency and Alternative Fuels law. In addition to alternative fuel use in "eligible" AFVs, state agencies can increase alternative fuel use in otherwise "exempt" vehicles by using an ethanol or biodiesel fuel mix.

Missouri could require conventionally fueled gasoline vehicles in state fleets to use E10 fuel (10 percent ethanol) outside non-attainment areas. As a step toward this goal, in February 1995, then Missouri Governor Carnahan issued an executive order requiring state-owned vehicles that do not operate on an alternative fuel to operate on a fuel ethanol blend when available and competitively priced and when not in an ozone non-attainment or maintenance area.

Missouri agencies should consider using B20 (20 percent biodiesel) fuel in fleet vehicles currently fueled with fossil diesel fuel. As documented in the technical options section, use of biodiesel fuel in the state fleet has increased during the past two years. This is partly in response to a change in the Energy Policy Act of 1992 (EPAct). EPAct was amended in 1998 to include biodiesel as an option for affected fleets to meet a portion of their annual AFV acquisition requirements through the purchase and use of biodiesel. Several state agencies are assessing opportunities to use biodiesel consumption to meet a portion of their EPAct AFV requirements.

Municipal governments and school districts in Missouri should assess the feasibility of substituting biodiesel for fossil diesel fuel. As discussed in the technical section of this report, the use of biodiesel in buses and other vehicles reduces CO₂ emissions.

Support Efforts by Municipal and Local Governments to Establish the Use of Alternative Fuels in Their Vehicle Fleets

State legislation has authorized a loan program to provide financial assistance to political subdivisions for establishing the use of alternative fuels in their vehicle fleets. The loans can be for the purchase of new AFVs, conversion of gasoline motor vehicles to run on alternative fuels or construction of refueling stations for AFVs. The Department of Natural Resources is developing rules to implement this program.

Recent state legislation permits school districts to establish contracts with nonprofit farmer-owned new generation cooperatives to supply bus fuel containing at least 20 percent biodiesel. The legislation also permits districts to receive additional state school aid to help with the incremental cost of the biodiesel, subject to appropriation.

Elevate the Priority of AFV and Alternative Fuel Use as a Principle of Fleet Management in Missouri

In general, managers of state agency and other public fleets that include a mix of AFV and conventional vehicles should develop fleet dispatch and fueling policies and procedures that assure maximum use of AFVs and low-carbon fuels consistent with the principles of efficient fleet management.

Collaborative government and industry efforts may provide opportunities to encourage private fleet managers to adopt similar practices.

Participate Actively in Collaborative Government and Industry Efforts to Create and Support Markets and Infrastructure for Alternative and Renewable Transportation Fuels in Missouri

As described previously, the EFC report states, “industry and government must share responsibility for creating and meeting demand for alternative fuels and vehicles...State, federal, local government and private fleet managers should work together to create demand for alternative fuels that is sufficient to support installation of alternative fuel refueling facilities.” (p. 83) Without infrastructure development, it will be extremely difficult for state agencies to meet their legal obligations to use alternative fuels in state-owned AFVs.

Continue to Participate Actively in the Clean Cities Programs in St. Louis and Kansas City and Consider Collaborative Efforts in Other Parts of Missouri

The U.S. Department of Energy's Clean Cities Program supports public-private partnerships that deploy alternative fuel vehicles and build supporting alternative fuel infrastructure. Unlike traditional command-and-control programs, the Clean Cities Program takes a voluntary approach to AFV development, working with coalitions of local stakeholders to help develop the AFV industry and integrate this development into larger planning processes.

For several reasons, Missouri should channel its efforts to promote alternative fuel infrastructure through the Clean Cities Program in areas where the program exists. First, a number of success stories indicate that the collaborative approach taken by the Clean Cities Program is both appropriate and effective. Second, federal sponsorship promotes the active involvement of fleet managers who are or might be subject to EPAct AFV requirements. Finally, federal sponsorship provides resources that would not otherwise be available.

Any municipality can create a Clean Cities Program. However, in practice, Clean Cities programs have been confined to cities that face air quality compliance issues, such as Kansas City or St. Louis. After establishing effective Clean Cities Programs in Kansas City and St. Louis, the state should consider ways to promote collaborative efforts in other parts of Missouri.

Support Federal Funding for Alternative Fuel Use by States

As recommended by the EFC, Missouri should “encourage the federal government to implement and support the alternative fuel use requirements of the Energy Policy Act of 1992. (EPAct),” (p. 82) including federal funding incentives authorized by EPAct to accelerate the use of alternative fuel vehicles by state government.

Support Measures that Reduce the Need for Travel and Support a Variety of Efficient Methods for Travel in Missouri

Implement Travel Policies and Procedures that Reduce Work-Related Travel by State Employees

Use Currently Available Teleconferencing and Other Communications Technology to Reduce the Need for Physical Meetings

Information on teleconferencing opportunities is presented in the technical options section of this chapter.

In implementing this option, it should be recognized that physical meetings may offer essential benefits that cannot be captured by teleconferencing. For example, physical meetings provide opportunities for face-to-face communication with other agency staff and stakeholders; opportunities to understand the geography and demographics of an area where projects are to take place; opportunities for site inspections; and the ability to work with maps, document archives and other paper documents that are not readily shared electronically.

Consider the Additional Measures Recommended in the Model Plan for the Fuel Conservation for State Vehicles Program and Incorporate These Measures into State Agency Fleet Plans

Examples of possible measures state agencies could adopt include the following:

- Establish policies that reduce the number of discretionary trips and require or favor travel by carpooling, rail or other public transportation when possible.
- Choose meeting locations that ensure maximum fuel conservation.
- Implement driver efficiency training workshops for state employees. As noted in the section on technical options, U.S. DOE studies indicate that the fuel economy of a vehicle can vary as much as 50 percent based on driving techniques.

Agencies Should Encourage and Provide State Employees with Options to Use Energy Efficient Means of Commuting to Work

Promote and Provide Incentives for Use of Carpools, Vanpools, Other High-Occupancy Vehicles and Non-Motorized Modes of Commuting Travel

Examples of possible policies and incentives include the following:

- Promote the establishment of carpools and vanpools and work with existing rideshare programs wherever feasible.
- Adopt flextime or staggered work schedules to reduce traffic congestion and support public transportation and carpooling.

- In congested areas, provide preferential parking for high occupancy vehicles.
- Explore the feasibility of establishing a parking voucher system to compensate state workers who choose efficient non-SOV modes for commuting to offices located in traffic-congested areas.

Consider Establishing a Pilot Telecommuting Program to Investigate its Feasibility and Effectiveness in Promoting Fuel Conservation and Other Goals

Information on telecommuting opportunities is presented in the technical options section of this chapter.

Consider Energy Implications of Commuter Travel in Making Agency Site Selection Decisions

Site selection has more impact on commuter-related energy consumption than any other variable. Strategies for energy efficient site selection were recommended in the 1995 edition of the *Model Plan for Fuel Conservation*.

Missouri Action Options for Reducing Greenhouse Gas Emissions – July 2002

Chapter 5

Options to Reduce GHG Emissions from the Agriculture and Forestry Sectors in Missouri

Chapter 5: Options to Reduce GHG Emissions from the Agriculture and Forest Sectors in Missouri

Background	181
Greenhouse Gas Emissions and Sequestration from Missouri's	
Agricultural and Forestry Sectors	182
Methane (CH ₄) Emissions from Agriculture	183
Nitrous Oxide (N ₂ O) Emissions from Agriculture	185
CO ₂ Emissions from Agriculture and Land Use Changes	186
CO ₂ Emissions from Energy Use in Agriculture	187
CO ₂ Emissions from Land Use Changes	188
Agriculture and Forestry Sector Technical Options to Reduce or	
Sequester Greenhouse Gas Emissions in Missouri	190
Opportunities to Reduce GHG Emissions from Missouri's	
Agricultural Sector	190
Opportunities to Reduce Methane Emissions	191
Opportunities to Reduce Nitrous Oxide Emissions	194
Opportunities to Reduce Carbon Dioxide Emissions	
Through Increased Energy Efficiency	196
Opportunities to Reduce GHG Emissions Through Renewable	
Energy Development in Missouri's Agricultural and	
Forestry Sector	201
Opportunities for Using Biomass from Missouri Farms	
and Forests	202
Opportunities for Farm-Based Wind Generation	207
Opportunities for Farm-Based Solar Energy Use	210
Opportunities to Offset GHG Emissions by Sequestering	
Carbon in Missouri Forests and Agricultural Soil	212
Agriculture and Forestry Sector Policy Options to Reduce or Sequester	
Greenhouse Gas Emissions in Missouri	223
Agriculture	223
Promote Use of Biomass, Wind and Other Farm-Based	
Renewable Energy	223
Promote Efficient Farm-Based Energy Use	227
Support Good Agricultural Management Practices that	
Reduce GHG Emissions	227
Promote Carbon Sequestration Programs and Practices	228
Forestry	230
Integrate Increased Carbon Sequestration and Sustainable	
Forestry Goals	231
Demonstrate Desirable Forest and Natural Landscape	
Management Practices on State-Owned Land	231
Encourage and Support Sustainable Forestry Practices by	
Private Landowners in Missouri	232

Expand Tree Planting and Other Land Cover on Missouri's	
Non-Forest Land	237
Monitor and Assess the Success of Voluntary Programs	239

Chapter 5 – Options to Reduce GHG Emissions from the Agriculture and Forestry Sectors in Missouri

Background

Agriculture and forestry are major contributors to Missouri's economy. Missouri's cash farm receipts and income for 1997 totaled \$5.56 billion, equally divided between receipts for crops (\$2.77 billion) and receipts for livestock and livestock products (\$2.79 billion). The two largest crops were soybeans (\$1.18 billion) and corn (\$0.78 billion). Agricultural and forestry products are a significant portion of Missouri exports.

More than 15 percent of Missouri's total labor force is employed in agriculture production and related agribusiness industries. Missouri has more than 100,000 farms, many of them small farms. In 1996, Missouri ranked second among U.S. states in the number of farms. However, the number of farms has steadily declined. More than half the farms in the state have market sales of less than \$10 thousand per year, indicating that farming is not the sole employment of the farm resident.

More than 30 percent of Missouri is forested land, described as central hardwood forest. Annual receipts of the forest products industry total about \$3 billion. The state is a leading producer of wooden pallets, charcoal and walnut products and exports lumber, hardwood flooring, whiskey and wine barrels, and treated wood products.

There is a twofold reason for including a chapter on Missouri agriculture and forestlands in this report. On the one hand, Missouri's agricultural sector is an important source of greenhouse gas (GHG) emissions. Missouri's agricultural sector is the leading source of methane and nitrous oxide emissions due to human activities in Missouri.¹

- Methane and nitrous oxide are highly potent greenhouse gases. As with GHG emissions from other sectors of the economy, good management practices can help reduce these methane and nitrous oxide emissions.
- Agriculture is an energy-intensive industry and therefore is a source of CO₂ emissions from energy use. In agriculture as in other sectors of the economy, increased efficiency and increased reliance on wind, biomass and solar energy sources can reduce CO₂ emissions from energy use.
- Finally, some land use changes such as the conversion of forest or farmland to urban uses can result in the release of soil carbon and the loss of carbon sinks. A sink is defined as a process or an activity that removes a greenhouse gas from the atmosphere.

On the other hand, Missouri's agricultural and forestry sector has great potential to reduce or offset GHG emissions from other sectors of Missouri's economy. Atmospheric concentrations of CO₂ can be lowered either by reducing emissions or by taking carbon dioxide out of the atmosphere and storing in it terrestrial, oceanic, or freshwater aquatic ecosystems. CO₂ can be kept out of the atmosphere through several land-use-based approaches including the following:

¹ *Inventory of Missouri's Estimated Greenhouse Gas Emissions in 1990* (Jefferson City, 1996) and *Greenhouse Gas Emission Trends and Projections for Missouri, 1990-2015* (Jefferson City, 1999).

- Adding or maintaining the planet's vegetative cover through reforestation, sustainable forestry and other means, thus enlarging living terrestrial carbon reservoirs.
- Increasing the carbon stored in non-living carbon reservoirs such as agricultural soils.
- Slowing or stopping the loss or degradation of existing forests and cropland, thus preserving current carbon reservoirs.
- Substituting sustainable biomass energy sources for fossil fuel consumption, thus reducing energy-related carbon emissions.

Missouri farmers and landowners could develop biomass, wind and other renewable energy resources of Missouri's agricultural and forested land. Other sectors of Missouri's economy could use electricity generated from solar, wind or biomass and fuels such as ethanol and biodiesel produced from biomass resources, reducing the GHG emissions that would otherwise result from energy use in these sectors.

A number of benefits in addition to the reduction of GHG emissions would result from the development of renewable energy resources in Missouri's agriculture and forest sector. The development of renewable energy could help meet Missouri's energy needs while reducing dependence on fossil fuels imported from outside the state. The development of renewable energy products and markets could provide new sources of profit to Missouri farmers and landowners and strengthen the economic vitality of Missouri's rural communities.

The maintenance of healthy, sustainable forest and croplands in Missouri helps sequester carbon that would otherwise be released to the atmosphere. Application of best management practices in agriculture results in increased sequestration of carbon as well as economic benefits to landowners and the general public and other environmental benefits such as flood and storm protection, watershed protection and prevention of soil erosion. Forestry best management practices, by enhancing soil and water protection, are important for protecting the environment when used in combination with forestry practices that improve forest health and vigor. These approaches are all based on the premise that adding to the planet's net carbon stores in vegetative cover or soil, or preventing any net loss, will help keep atmospheric CO₂ levels lower than they would otherwise be.

Greenhouse Gas Emissions and Sequestration from Missouri's Agricultural and Forestry Sectors

Two previous reports described and estimated greenhouse gas emissions or sequestration from agricultural and forestry sources. The *Inventory of Missouri's Estimated Greenhouse Gas Emissions in 1990*, hereafter referred to as the *1990 Inventory*, estimated 1990 emissions and included a great deal of technical discussion of the factors influencing methane and nitrous oxide emissions from various biological processes found in forests and agricultural operations as well as land use changes affecting forest and agricultural land.

A follow-up study, *Greenhouse Gas Emission Trends and Projections for Missouri, 1990-2015*, hereafter referred to as the *Trends and Projections Report*, refined and extended GHG emissions estimates from the first report and discussed the extension of forest sequestration to include consideration of sequestration of carbon in wood products and landfill materials that originated from woody biomass in forests.

The following sections summarize, refine and extend material from these previous studies.

Methane (CH₄) Emissions from Agriculture

Methane (CH₄) is a highly potent greenhouse gas. The *1990 Inventory* estimated that methane accounted for about 11 percent of all GHG emissions in Missouri and identified two major sources of anthropogenic (from human sources) methane emissions in Missouri – waste disposal in municipal and industrial landfills, which are discussed in another chapter of this report, and agricultural sources, particularly methane emissions from livestock. Together, these accounted for more than 95 percent of anthropogenic methane emissions in that year.

The two biological processes involved in methane emissions from livestock operations are enteric fermentation in livestock digestive systems and anaerobic decomposition of livestock manure. Enteric fermentation occurs during digestion when microbes that reside in animal digestive systems break down feed consumed by the animal. The amount of methane produced by an individual animal depends upon its digestive system and the amount and type of feed it consumes. Ruminants such as cattle have the highest methane emissions among all animal types because a significant amount of methane-producing fermentation occurs in their fore-stomachs. Although sheep and goats are also ruminants, they accounted for less than 1 percent of methane emissions from livestock digestive systems in Missouri.

The decomposition of livestock manure produces methane when microorganisms metabolize organic material in the manure. Under anaerobic conditions, the organic material is decomposed by anaerobic and facultative (living in the presence or absence of oxygen) bacteria. The end products of anaerobic decomposition are methane, carbon dioxide and stabilized organic material.

Most of the methane emissions from manure management systems in Missouri come from swine and dairy operations because they rely heavily on anaerobic lagoons to dispose of manure. Anaerobic lagoons are typically automated flush systems that use water to transport the manure to treatment lagoons where it resides for periods ranging from 30 days to over 200 days. The length of time depends on the lagoon design and other local conditions. The water from the lagoon is often recycled as flush water and may be used for irrigation on fields with the treated manure providing fertilizer value.

Anaerobic lagoons generate close to the maximum methane potential of the waste as measured by a methane conversion factor (MCF) of 80 percent.² The 1990 Inventory estimated that emissions from anaerobic lagoons accounted for over 95 percent of total emission from manure management in that year.

Most other livestock systems, including that of beef cattle, are managed in Missouri using “dry” systems that promote conditions that limit methane production. The primary exception is widespread use of liquid slurry systems to manage waste from poultry operations. Liquid slurry systems are characterized by large concrete lined tanks built into the ground where waste is stored for six or more months until it can be applied to fields. Liquid slurry systems produce

² MCF is included in the U.S. Environmental Protection Agency (EPA) *State Workbook* methodology for estimating methane from manure management systems.

more methane than dry systems but according to the *State Workbook*, they have an MCF of only 24 percent compared to an 80 percent MCF factor for anaerobic lagoons.

Current dairy, swine and beef manure management systems in Missouri are further described in a series of recent Cooperative Extension publications that are readily available on-line.³

The *1990 Inventory and Trends and Projections Report* estimate and project methane emissions from beef, dairy and swine operations for the years 1990- 2015 under “business-as-usual” conditions. Table 1 summarizes these estimates.

Table 1: Estimated and Projected Methane Emissions from Swine and Cattle Operations, 1990-2015 (tons)

	Cattle	Swine	Total
Enteric fermentation			
1990	6.1	0.1	6.2
1996	6.5	0.2	6.7
2015	5.9	0.2	6.1
Manure management			
1990	1.4	2.6	4.0
1996	1.2	3.2	4.4
2015	0.7	3.5	4.2
Total			
1990	7.5	2.7	10.2
1996	7.7	3.4	11.1
2015	6.6	3.7	10.3

As Table 1 indicates, total estimated GHG emissions from methane from livestock operations increased by almost a million short tons carbon dioxide equivalent (STCDE) between 1990 and 1996, with increases in emissions from swine and beef cattle operations offsetting decreases from dairy cattle operations. However, by 2015, total methane emissions are projected to decrease to nearly their 1990 level.

Driving these estimates is the expectation that Missouri’s dairy industry will continue to shrink. From 223,000 head in 1990, the number of dairy cattle is projected to decrease steadily to about 89,000 head in 2015.

³ *Economic Considerations for Dairy Waste Management Systems*, WQ302, reviewed 1994; *Dairy Waste Management Systems in Missouri*, WQ301, 1995; *Beef Manure Management Systems in Missouri*, EQ377, 2000; and *Swine Manure Management Systems in Missouri*, EQ350, 2001.

Offsetting this decline, the number of swine and beef cattle is projected to increase from 1990 through about 2005, with beef cattle increasing from 81,600 head in 1990 to about 87,200 head in 2005 and swine increasing from about 2.8 million animals in 1990 to over 4 million animals in 2005. After 2005, beef and swine numbers are projected to decrease slightly to about 86,300 head of beef cattle and 3.8 million swine in 2015.

The *1990 Inventory and Trends and Projections Report* provide a detailed explanation of the methodology used to develop these estimates of livestock numbers and methane emissions.⁴

Two other agricultural sources of methane emissions in Missouri are rice cultivation and burning of crop wastes, both localized in the Missouri Bootheel. As discussed in the *Inventory and Trends* reports, neither of these sources is a very significant source of methane emissions.

Nitrous Oxide (N₂O) Emissions from Agriculture

Nitrous oxide (N₂O) is produced from soil nitrogen through the microbial processes of denitrification and nitrification.⁵ Use of nitrogenous fertilizers leads to an increase in the availability of nitrogen in the soil. While many factors affect the level of denitrification and nitrification that takes place, on average an increase in the availability of nitrogen in the soil leads to a linear increase in the amount of N₂O that escapes into the atmosphere.

Using data collected by Missouri's Fertilizer Control Services and U.S. EPA methodology, the Energy Center's *1990 Inventory* study estimated that the use of nitrogenous fertilizer led to emissions of about 7.3 thousand tons of N₂O in Missouri in 1990, equivalent to about 2.3 million tons of CO₂ (STCDE). However, this is a midpoint estimate of a very large range of possible values. Taking into account the variety of factors that could affect emissions, N₂O emissions might have been as low as .2 million carbon tons equivalent (MCTE) or as high as 4.5 MCTE.⁶

Using data on nitrogenous fertilizer use through 1996, and assuming a continuation of business-as-usual practices, the *Trends and Projections Report* estimated that N₂O emissions remained more or less constant through 1996 at about 2.3-2.5 MCTE and projected that they would continue at this level through 2015. Fertilizer data available since the *Trends and Projections Report* was prepared appears to indicate an upward trend in nitrogenous fertilizer application since 1996. As Table 2 indicates, average tons of nitrogenous fertilizer applied statewide during 1995-2000 was about 4 percent higher than average tons applied during 1989-94. All else being

⁴ Historic livestock population data was taken from the 1990 to 1995 editions of Missouri Department of Agriculture *Missouri Farm Facts*. Projections of livestock population were extrapolated from national and state projections prepared by the Food and Agriculture Policy Research Institute.

⁵ Denitrification is the process by which nitrates or nitrites are reduced by bacteria and which results in the escape of nitrogen into the air. Nitrification is the process by which bacteria and other micro-organisms oxidize ammonium salts to nitrites, and further oxidize nitrites to nitrates.

⁶ Department of Natural Resources' Energy Center, *Inventory of Missouri's Estimated Greenhouse Gas Emissions in 1990*, p. 118; and Energy Center, *Greenhouse Gas Emission Trends and Projections for Missouri. 1990-2015*, p. 298. As noted in these reports, these estimates, which follow U.S. EPA guidelines, are based on a methodology that does not explicitly account for many factors known to affect emissions and on coefficients derived for average factors across the United States. Therefore, these estimates must be considered a rough approximation of actual emissions.

equal, this suggests that N₂O emissions may have increased by that amount since 1990.⁷ However, this amount of increase is small compared to uncertainties due to weather and other factors.

Table 2: Nitrogenous Fertilizer Use in Missouri, 1989-2000

	Actual Use (1,000 tons) 3-year average	
1989	418.5	
1990	379.0	396.6
1991	392.3	405.9
1992	446.3	417.1
1993	412.7	430.0
1994	431.1	408.9
1995	383.0	405.1
1996	401.2	408.8
1997	442.4	424.4
1998	429.5	441.8
1999	453.6	452.7
2000	475.0	464.3

Many factors besides the amount of fertilizer applied can affect the actual level of N₂O emissions. The most important is weather. Warm, wet weather in May and June is likely to lead to large losses of nitrogen in the form of N₂ and N₂O.⁸ Weather is responsible for most of the uncertainty and variability in amounts of N₂O produced.

CO₂ Emissions from Agriculture and Land Use Changes

The *1990 Inventory and Trends and Projections Report* identify three agricultural sources of CO₂ emissions: energy use, land use changes and the use of agricultural lime.

As explained in the *1990 Inventory*, agricultural lime is applied with the intention that it will decompose into calcium and various byproducts. One of the byproducts of decomposition is CO₂. The *1990 Inventory and Trends and Projections Report* include a full discussion of the methodology used to estimate CO₂ emissions from this source and project them through 2015.

⁷ UMC Agricultural Experiment Station, *Missouri Fertilizer Tonnage Report 2000*, "Fertilizer and Plant Food Tonnages Shipped for Use in Missouri since 1949"

⁸ Other non-managerial factors include availability of oxygen, porosity, pH, organic carbon content, thaw cycle, micro-organisms present and soil type. Experiments have shown that increases in pH, soil temperature, soil moisture, organic carbon content, and oxygen supply may increase N₂O emissions. A factor that probably increases N₂O emissions in Missouri is the prevalence of high-clay, poorly-drained soils, particularly in the northeastern part of the state.

Missouri farmers have available to them a number of sources, including the MU Cooperative Extension Service, for technical advice on the proper application of lime. Since CO₂ emissions from this source are projected to decline about 20 percent through the projection period, from about 590,000 tons STCDE in 1990 to about 415,000 tons in 2015, they are not further discussed in this report.

CO₂ Emissions from Energy Use in Agriculture

U.S. agricultural operations, like those in other developed nations, are energy intensive. In preparing its *Annual Energy Outlook*, U.S. Department of Energy (DOE) estimates on-site energy consumption by agriculture at a national level. The consumption estimates provided by the *Annual Energy Outlook 2002* are as follows. As these estimates indicate, U.S. agricultural production relies heavily on petroleum, especially diesel fuel, for on-site energy needs.

Table 3: Estimated Energy Consumption in U.S. Agriculture, 2000

	Consumption (Trillion Btu)	Percent of total
Petroleum		
Diesel	508.2	41%
Propane	211.2	17%
Gasoline	104.3	8%
Other	101.2	8%
Total	924.9	74%
Natural Gas	96.9	8%
Coal	0.5	0%
Renewables	23.4	2%
Electricity	196.1	16%
Total	1,241.8	100%

As Table 3 indicates, agriculture in the United States and Missouri relies heavily on petroleum, especially diesel fuel, to meet its direct energy consumption needs.

In discussing energy use in agriculture, it is conventional to distinguish between “direct” on-site energy use and “primary” energy use. “Primary” energy use includes the energy embodied in agricultural inputs. The estimates in Table 3 are for on-site energy consumption only.

The energy consumption data that would be required to estimate CO₂ emissions from energy use in Missouri agriculture is not readily available. The estimates shown in Table 3 are based on national modeling and do not extend to the state level. U.S. Department of Agriculture/ERS

ceased collecting data on national agricultural energy use in 1992⁹ and has never collected state-level data on energy use in agriculture.

U.S. DOE's *State Energy Data Report* estimates agricultural energy use, including fuel use for off-road farm machinery, as part of industrial sector energy use. The industrial sector also includes manufacturing, mining, fisheries and forestry. There is no reliable way to disaggregate this data to estimate agricultural energy use at the state level.

Reflecting the lack of data, neither U.S. EPA nor U.S. DOE estimates CO₂ emissions from agricultural energy use in their annual greenhouse gas inventories. State GHG emissions inventories do not customarily include an estimate for CO₂ emissions from the agricultural sector.

CO₂ Emissions from Land Use Changes

Land-use changes frequently affect net sequestration of carbon and emissions of CO₂. On the one hand, the conversion of pasture or crop land to forestland may increase the rate of carbon sequestration. On the other hand, forestland may be converted to agricultural uses such as pasture, releasing carbon that was stored in woody biomass. Finally, forest, crop or pasture land may be converted to urban land, decreasing carbon sequestration. Such conversions to urban use are generally permanent and result in an irreversible loss of carbon sinks.

Even if land use losses in one area are offset by gains in another area, the conversion process may lead to net losses of carbon stocks, at least in the short term. The process of converting agricultural land from one use to another can disturb and release soil carbon even if the land later reverts to its original use. The conversion of mature forestland can result in the loss of a large quantity of biomass that requires many years to re-establish.¹⁰

The *1990 Inventory* estimated that land use changes in that year led to net CO₂ emissions totaling over 2.2 million tons of CO₂.¹¹

This was the net result of many land use changes. For example, the conversion of forest and agricultural land to urban land resulted in about 560,000 tons of CO₂ emissions in 1990, according to the *1990 Inventory*. Conversion to urban land has continued to occur in Missouri. Between 1982-1997, according to National Resource Inventory (NRI) data, 159,000 acres of forestland, 133,000 acres of pasture land and 99,000 acres of crop land were converted to "developed" (urban) uses

The conversion of forestland was the leading source of CO₂ emissions from land use changes in 1990. Conversion of forestland averaged 41,000 acres between 1989 and 1992. Assuming that 1990 was an average year, these losses resulted in estimated emissions of over 2.3 million tons of

⁹ Personal communication, Crawford Honeycutt, U.S. DOE Energy Information Administration (EIA), February 25, 2002

¹⁰ Some but not all of the carbon that was stored in the woody biomass of a converted mature forest may continue to be sequestered for a number of years in the wood product pool. This is not adequately accounted for in EPA's State Workbook methodology for estimating changes in carbon stocks from land use changes

¹¹ This estimate was based on analysis from the 1982 and 1992 Summary Report of the National Resource Inventory (NRI) conducted by USDA/Natural Resources Conservation Service (NRCS).

CO₂ in 1990. Conversion of forestland to pasture land totaled about 25,800 acres and resulted in release of 1.4 million tons of CO₂. Conversion of forestland to developed land including urban use totaled about 7,400 acres and resulted in the release of nearly a half million tons of CO₂. The remaining conversions of forestland were to crop, hay and other uses.

Counterbalancing conversions of forestland, nearly 96,000 acres of pasture land per year reverted to forestland between 1982 and 1992. Data from the 1997 NRI survey indicates that these trends continued. Between 1982 and 1997, more than 600,000 acres of forest land were converted to other uses but this was offset by an increase of nearly 1.7 million acres of new forest land, leading to a net gain of about a million acres of new forest land in the state.¹² Nearly 85 percent of the new forest land came from pasture land that was taken out of cattle production and allowed to revert to forest.

Even though more forestland was being gained than lost during these years, the gains in forestland did not fully offset the loss in carbon stock caused by forestland conversion, at least in the short term. There was a short-term net loss in carbon stocks because mature forestland was being lost and the forestland being added was still in an early successional stage.

When pasture land is allowed to revert to forest land, the existing biomass (primarily grass) is usually left untouched while new biomass (young tree seedlings) become established along with the existing grass cover. If the tree seedlings on newly converted forestland are allowed to grow to maturity and especially if the newly converted forestland is managed in a sustainable manner, the carbon sink represented by mature forestland that was lost should eventually be restored or even increased.

Missouri's forest management strategy relies primarily on natural regeneration to restock its forest reserves. Although some tree planting does occur throughout the state, it is not a major forest restocking component. In Missouri's oak-hickory forests, carbon sequestration during the initial stages of regrowth is low. For most hardwoods, the rate of net primary production increases during early stand development, peaking when the trees reach an age of 10 to 30 years. The rate slowly declines about the time of canopy closure. For pines and other species, the rate of productivity and decline is somewhat later. Taking into account the general trend for all forest biomass during the period of regrowth, carbon sequestration increases slowly for a period of 20 to 30 years. The rate of carbon sequestration continues to increase linearly until forests mature, which requires 40 to 60 years on average in Missouri. After reaching a total carbon level averaging 19.7 tons per acre, the quantity of carbon sequestered gradually declines. Although the initial carbon sequestered during the first year of regrowth may be low, sequestration over the period of time it takes the forests to reach their full carbon potential can be significant.¹³

The data and methodology required to determine whether this is occurring are not currently available. Due to its aggregate nature, NRI data is insufficient to determine whether this is occurring. Extensive interviews with foresters and county agents would be required to determine how newly forested land has been managed. Furthermore, as was discussed in the 1990

¹² Personal communication, Terry Barney, USDA/NRCS, State Office, Columbia, Mo, February 28, 2002.

¹³ This discussion is excerpted from the Inventory of Missouri Greenhouse Gas Emissions in 1990. Primary sources were EPA, 1992. *State Workbook; Methodologies for Estimating Greenhouse Gas Emissions*, EPA-230-b-92-002, Office of Policy, Planning, and Evaluation; Rebertus, Alan, Ph.D., 1995. School of Natural Resources, University of Missouri-Columbia, Columbia, MO. Personal Communication, August 1995.

Inventory, U.S. EPA's *State Workbook* methodology for estimating changes in carbon stocks from land use changes does not provide a method for estimating long-term gains. Development of adequate data and methodology to monitor the progress of new forest land in Missouri should be part of the data development effort recommended in the policy section of this chapter.

One consequence of extensive conversion from and to forestland in Missouri is forest fragmentation. Forest fragmentation, a major conservation issue in the Midwest that has been addressed by much recent research, generally reduces average forest patch size and the amount of forest interior or core area. NRI data showing a net gain in forested land in Missouri and other states within the central hardwoods region of the United States cannot adequately address fragmentation because it is not spatially referenced. Thompson has surveyed available data for assessing forest fragmentation in the central hardwoods region including Missouri and concludes that fragmentation has undoubtedly occurred but that better data is required to assess fragmentation trends.¹⁴

Agriculture and Forestry Sector Technical Options to Reduce or Sequester Greenhouse Gas Emissions in Missouri

The discussion of technical options falls into three parts:

- 1) Opportunities to reduce emissions of methane, nitrous oxide and carbon dioxide from Missouri's agricultural sector. This includes a discussion of opportunities to increase the efficiency of energy use in agriculture. There may be additional opportunities to improve efficiency in industries that process food and forestry products but these are probably addressed more effectively at an industry level rather than through state policy.
- 2) Opportunities to reduce GHG emissions by using or developing biomass, wind and solar renewable energy resources in Missouri's agricultural and forestry sector, reducing the use of imported fossil fuels that would otherwise have occurred.
- 3) Opportunities to sequester carbon in Missouri's forests and agricultural soil. Forest and soil management practices can preserve and extend the substantial annual sequestration that already occurs.

All technical options presented could reduce net state GHG emissions while providing numerous other environmental and economic benefits to farmers, landowners and all Missourians.

Opportunities to Reduce GHG Emissions from Missouri's Agricultural Sector

For simplicity, this chapter provides separate discussion of technical options for each of the three primary greenhouse gases – methane, nitrous oxide and carbon dioxide. However, it must be recognized that agriculture and forestry involve biological processes in which factors that affect emissions of these three gases may interact. Technologies that influence the emissions of any single gas may have ramifications for the other gases. Interactions among greenhouse gases should be taken into account when designing or assessing specific GHG reduction projects.

¹⁴ Thompson, Frank, USDA Forest Service, Columbia, Missouri, "Fragmented Midwestern Forests and Songbird Populations: Where Do We Go From Here?"

For example, adding lime to claypan soils could reduce N₂O emissions by increasing soil pH but would increase emissions of CO₂ since carbon dioxide is one byproduct of lime decomposition. Similarly, conservation tillage methods help sequester CO₂ by increasing soil carbon but if not properly managed, may also increase N₂O emissions by speeding up denitrification. However, research at the University of Missouri and elsewhere in the Midwest has identified productive and profitable nitrogen management practices for no-till corn production that can alleviate this potential problem.¹⁵

Opportunities to Reduce Methane Emissions

Technical Options to Reduce CH₄ Emissions from Enteric Fermentation in Cattle

The primary opportunity to reduce enteric fermentation in cattle involves modifying the animals' diet. In general, feed changes that improve animal productivity also reduce enteric fermentation. When productivity of the animal is improved, feed energy associated with maintaining the animal is reduced and methane emissions per unit of product are also reduced. Some diet changes that reduce enteric fermentation also produce leaner meat that may have greater market value. Thus, a number of diet changes that reduce enteric fermentation are compatible with broader goals of improving animal health and increasing the profitability of the livestock operation.

Extensive technical literature discusses the impact on enteric fermentation and the side effects of adding fats, additives and other components to animal diets. Discussion of this literature is beyond the scope of this study.

It has been suggested that the greatest opportunities to reduce enteric fermentation through modification of animal diets may exist in developing nations. One source describes several technologies that are "currently available in natural forms, have low to medium capital requirements and are estimated to reduce ruminant livestock methane per unit of product by 25 percent to 75 percent."¹⁶

This project has not attempted to assess opportunities to improve animal diets in Missouri dairy and beef operations. Such assessments probably occur most effectively at an operation-specific level in the context of consultations with an animal husbandry specialist from the MU Cooperative Extension Service or some other source.

Technical Options to Reduce CH₄ Emissions from Manure Management

The most promising opportunity to reduce atmospheric emissions of methane from animal waste is installation of anaerobic digesters to capture methane for use as an energy source.

¹⁵ UMC Cooperative Extension publication G9175, *Nitrogen Management for No-Tillage Systems in Missouri*. John Stecker, the author of this publication, does not believe that N₂O is a major issue in Missouri conservation tillage systems. Personal communication, March 4, 2002.

¹⁶ Wittenberg, Karin and Dinah Boadi, *Reducing Greenhouse Gas Emissions from Livestock Agriculture in Manitoba*, Manitoba Climate Change Task Force, Public Consultation Sessions, May 11 2001; Gerald Turnbull and Bernard Du Charmé, *Methane Emissions – Reductions from Ruminants*, *Environmental Finance*, February 2001, p 24

Captured methane could be used either in the farm home or the farm operation. Table 4 presents Fulhage's¹⁷ estimate of the number of animals required to serve several typical farm home applications, based on the heat value of the methane that could typically be obtained per animal as well as assumptions about each application's energy requirements. The use of highly efficient home appliances could reduce the requirements shown in the table whereas use of less efficient appliances might increase them.

Table 4 - Comparison of Some Typical Farm Home Heat Requirements and the Number of Animals Needed to Meet These Requirements

	Heat requirement (Btu/hr)	Swine (150 lbs.)	Dairy (1,200 lbs.)	Poultry (4 lb. bird)	Beef (1,000 lbs.)
Kitchen range ¹	65,000	77	14	1,547	11
Water heater ²	45,000	107	20	2,143	15
Refrigerator ³	3,000	22	4	429	3
Heat 1,500 sq. ft. home ⁴	37,500	535	99	10,714	72
¹ Assumed to operate 2 hrs/day, i.e., 24-hr average of 5,417 Btu/hr ² Assumed to operate 4 hrs/day, 24-hr average = 7,500 Btu/hr ³ Assumed to operate 12 hrs/day, 24-hr average = 1,500 Btu/hr ⁴ Assumed 25 Btu/hr/sq. ft. heat requirement					

A farm operation application of methane from a digester might be water heating in a dairy operation or generating electricity for niche applications such as lighting, pumping and ventilation. As Fulhage demonstrates, heat requirements of farm operations such as grain drying or tractor operation are too large to be served by a typical digester.

In addition to the production of methane as a renewable energy resource, the economic benefits of installing and operating an anaerobic digester include:

- Nearly complete stabilization of raw manure. The effluent from a properly operating digester is relatively odor-free. Odor problems usually associated with production facilities and disposal operations may be reduced.
- Reduction in amount of solids to be handled. However, the digester does not reduce the volume of liquid that must be handled. Digester effluent cannot be discharged into streams. A lagoon will probably be required for storage of digester effluent until such time that it can be distributed over the land.

¹⁷ Fulhage, Charles D., Dennis Sievers and James R. Fischer, *Generating Methane Gas From Manure*, University of Missouri-Columbia Extension Bulletin G1881

- Production of potentially valuable co-products including the digested solids. Nearly complete retention of the fertilizer nutrients (N, P, K) that were in the raw manure. Economic value depends on current fertilizer price.

These benefits must be weighed against the capital and management requirements of installing and operating an anaerobic digester. Because the process of anaerobic digestion is biologically based, each potential project must be individually evaluated. Factors for success include an adequate match of digester type to the farm's manure management program; competent design and installation, simplifying digester operation and maintenance; and proper management of the chemical and physical environment within the digester, which is essential to sustained performance.

Appendix 1 lists 31 methane digester systems currently in operation at commercial livestock farms in the United States. Of these, 15 are located on swine farms, 14 on dairy farms, and two on caged layer farms. According to U.S. EPA calculations, the 31 operating digesters prevented over 4,800 metric tons of methane from entering the atmosphere (approximately 27,500 metric tons on a carbon-equivalent basis).

In 23 of the 31 systems, the captured biogas is used to generate electrical power and heat. In 1999, these systems in total produced roughly 1 million megawatt hours (MWh) of power. The remaining eight systems flare the captured gas for odor control.

If a number of installations have succeeded in the United States, an equal number have failed. Lusk has surveyed both the operating and failed digesters and concludes that the success rate depends partly on the type of digester built as well as the quality of up-front technical analysis and design. He also notes that digester technology and design have improved substantially since the first units were built in the 1970s and 1980s.

Among the types of farm-based digesters actually built, the failure rates for complete-mix and plug-flow technologies are staggering – 70 percent and 63 percent, respectively. For covered lagoon digesters, the failure rate is 22 percent. Because there are fewer operating slurry digesters, their current 100 percent success rate is certainly inconclusive. Once slurry digesters have a larger market share, the opportunity for system failures caused by poor design, fabrication, and operation will be more equal to that of the other technologies, and the slurry digesters performance can then be gauged.

The reliability of the digesters constructed since 1984 is far better than for those constructed from 1972-1984. This is generally due to a more simplified digester design.¹⁸

The most likely candidates for digesters in Missouri are confined animal feeding operations (CAFOs) that must dispose of manure from a large number of animals and may have odor problems. While the disposal of manure from confined dairy, swine, and poultry farms has created new environmental challenges,¹⁹ the growth of these operations also has created new opportunities for economic recovery of methane as a renewable energy source.

¹⁸ Lusk, P, *Methane Recovery from Animal Manures: A Current Opportunities Casebook*. 3rd Edition. NREL/SR-25145. Golden, CO: National Renewable Energy Laboratory, 1998.

¹⁹ In addition to methane, potential pollutants from decomposing livestock manures include biochemical oxygen demand (BOD), pathogens, nutrients and ammonia emissions. The major pollution problems associated with these wastes are surface and groundwater contamination and surface air pollution caused by odors, dust, and ammonia.

Because dairies need hot water every day of the year, large dairy operations may be good candidates for methane digesters. However, most of the dairies in Missouri are small and probably could not capture methane cost-effectively. The largest dairy in Missouri, operating with about 3,000 milking cows in the northeast part of the state, has been considering construction of a digester. The other very large dairy in the state has about 1,000 milking cows.

Analysis using FarmWare, a computer decision-aid program developed by U.S. EPA's AgStar Program, has indicated that the break-even point for a swine facility using a covered lagoon would be about 2,000 pigs. As Table 5 indicates, one result of the restructuring of Missouri's swine industry is that there are a number of swine CAFOs with at least this number of animals.²⁰

Table 5 – Confined Swine Feeding Operations and Lagoons in Missouri

	Number of animal units (as defined by U.S. EPA)	Total swine operations (Missouri data)	Total lagoons (Missouri data)
Class 1A	More than 7,000 animal units	13	133
Class 1B	3,000 to 6,999 animal units	25	64
Class 1C	1,000 to 2,999 animal units	122	165

However, some of FarmWare's assumptions may not apply to Missouri. First, the FarmWare analysis assumes a lagoon cover rather than a complete mix digester. Covers are not a proven technology in Missouri given the state's diverse weather conditions that may include winds that could rip or balloon covers and winter buildup of ice or snow.

Second, the FarmWare analysis assumes a retail rate for electricity at 8 cents to 10 cents per kilowatt hour (kWh) and further assumes that the farmer can sell excess power to the utility at this price. The retail price of electricity is less than 8 cents in Missouri and the price at which Missouri utilities would purchase excess electricity from farmers might well be closer to 3 cents per kWh. Direct use of heat by the CAFO might be a better option from an economic standpoint.²¹

Opportunities to Reduce Nitrous Oxide Emissions

Missouri farmers are generally aware of management practices that minimize the loss of nitrogenous (N) fertilizer as N₂O. These include tailoring the application of fertilizer to the requirements of the crop and applying fertilizer as close as possible to the time it will be needed by the crop. These practices, which are strongly supported by the MU Cooperative Extension Service and other technical resources available to Missouri farmers, tend to reduce N₂O emissions as well as decrease impacts on water quality and the farmer's operating cost for fertilizer.

²⁰ Source: Missouri Department of Natural Resources Solid Waste Management Program (SWMP), WQIS database. Personal communication, Steve Tackett, SWMP, March 26, 2002.

²¹ Personal communication, Vicky Kugler and Roger Korenberg, Department of Natural Resources Environmental Assistance Office, March 26, 2002.

As described in this section, new technology that is close to commercial availability would allow more precise management of N fertilizer, making it possible to reduce nitrogen application by 15 to 20 percent.²² On average, a reduction of 15 to 20 percent in application of N fertilizer would reduce N₂O emissions by the same amount, although denitrification would continue to vary from year to year due to the influence of factors such as weather. It is possible that a reduction of 15 to 20 percent in nitrogen applied could have an even larger impact on water quality.

In Missouri, as in the Midwest generally, intensive fertilizer use, which tends to increase emissions, is an important component of agricultural strategy that emphasizes high crop yields. High application rates are common in counties with high production of corn, wheat and sorghum, such as those in northeast Missouri and the Bootheel. Fertilizer is used less intensively in counties that emphasize livestock and hay production, as in the Springfield Plateau in south central Missouri.

Farmers may consider over-application of N fertilizer a form of risk reduction given the uncertainty of factors such as weather that may lead to higher than expected nitrogen loss later in the year. If a portion of fertilizer could be applied at planting time and another portion later in the growing season, the risk of fertilizer loss and accompanying yield loss could be reduced, but such split application is itself risky because bad weather could make the later application of fertilizer difficult and expensive. If risk management instruments such as insurance could be developed, split application might seem more feasible.

For corn, MU Cooperative Extension Service agronomists currently recommend that as a rule of thumb, farmers apply about 1.2 pounds of nitrogen per bushel of expected yield. However, actual N requirements vary widely both between fields and within fields. If farmers had better tools to identify the actual N requirements of particular areas of cropland, it would be possible to reduce the average application of N, reduce the farmer's expenditure for fertilizer and reduce the environmental impact from "wasted" nitrogen that is not taken up by the corn itself but escapes into water or the atmosphere.

With techniques to determine actual N requirements, average application could probably be reduced to about a pound of N per bushel of yield. Even with precise application based on actual N requirements, it probably is not possible to reduce nitrogen application to corn fields below the rate of a pound of N per bushel on a sustained basis. About 0.75 pounds of N is taken from the soil per bushel of corn and at normal yield levels there inevitably will be additional loss of about 0.25 pounds of N per bushel through processes such as leaching and denitrification.

At present, the only commercially available method for determining precisely how much nitrogen should be applied to fields is through analysis of deep soil samples, a process that is expensive and not always accurate. Agronomists in a number of states are working to develop more accurate and cost-effective methods to determine the optimal level of N application.

One promising approach is the analysis of crop color in aerial photographs or with vehicle-mounted sensors, which can determine optimal N application rates with greater precision and coverage than soil samples. This technology is currently at the field test stage. A December 1999 survey of Missouri professional chemical applicators, managers, consultants, and seed and

²² This estimate and other technical information were provided by Peter Scharf, University of Missouri Cooperative Extension. Personal communication, February 26, 2002.

chemical dealers by University of Missouri researchers, indicated that most agreed that precision farming techniques such as those described here improve efficiency, fertility and crop yields.²³

When this technology becomes commercially available, it is likely that the farmer's savings on the cost of fertilizer will be about equal the cost of obtaining the analysis of N requirements. It will require sustained federal and state commitment to continued research, infrastructure development and cost-sharing to make this or similar technology attractive and commercially available to farmers. A well-planned program of technical assistance and incentive programs could be very effective in improving nitrogen application.

Such a public commitment could be justified on the basis of potential economic and environmental benefits. In addition to reduction of N₂O emissions and improvements in water quality, other economic and environmental benefits include:

- Improved fertilizer management decreases the susceptibility of agriculture and the general economy to natural gas price shocks. Most of the cost of producing N fertilizer is the cost of the natural gas, which is used as a source of both energy and chemical-reducing power to convert nitrogen gas (from the air) to ammonia. All other N fertilizers are then produced from ammonia.

High natural gas prices in 2000-2001 led many U.S. ammonia production facilities to shut their doors; some of the older ones will probably never come back on line. Agricultural profit margins were severely affected and many farmers were forced to change production plans due to the high cost or unavailability of fertilizer.

- Techniques for applying N fertilizer to precisely meet crop needs could be an important component of a national plan to help reduce hypoxia in the Gulf of Mexico. Hypoxia is a condition of low oxygen, specifically defined as less than 2 parts per million. Normal oxygen levels in water run 4 to 6 parts per million. Each summer, a large hypoxic zone appears in the shallow waters along the Louisiana shoreline of the Gulf of Mexico. U.S. EPA's draft action plan for addressing Gulf hypoxia posits that nitrogen from N fertilizer use in Missouri and other Midwestern states ends up being carried by the Mississippi River to the Gulf and causing hypoxia. While further work is needed to fully understand the sources of nitrogen, efforts to reduce nitrogen loss from farm fields is a critical component of the Action Plan for reducing gulf hypoxia, and all parties agree in the value of efforts to reduce nitrogen loss or reduce the amount of nitrogen leaving farm fields.

Opportunities to Reduce Carbon Dioxide Emissions Through Increased Energy Efficiency

Combustion of fossil fuels in agriculture, as elsewhere in the industrial sector, results in emissions of CO₂ and emissions of criteria air pollutants such as nitrogen oxide (NO_x). Indirectly, use of electricity in agriculture has the same indirect result because most electricity in Missouri is generated at fossil-fired power plants. Increased energy efficiency reduces the air emissions associated with agricultural production.

²³ Parcell, Joe and Ray Massey, *Use and Perceptions of Precision Agriculture Technologies by Professional Chemical Services*, University of Missouri, 1999.

The reliance of U.S. agriculture in general, and Missouri agriculture in particular, on petroleum and natural gas renders agriculture highly vulnerable to fossil fuel price shocks. For example, farmers' profit margins were severely affected by high diesel and natural gas prices in 2000-2001. Natural gas shortages and high natural gas prices during this period shut down a portion of fertilizer production in the United States and forced many Missouri farmers to change production plans.

Between 1997 and June 2000, total fuel costs per Missouri farm increased 24.5 percent. Based on June 2000 prices, estimates indicate each Missouri farm spent an average of \$3,222.70 for fuel in 2000, which consumed 19.64 percent of farm income.²⁴

Increased energy efficiency in agriculture, as in other businesses, benefits both the farmer and society. By improving the productivity of the farm enterprise, increased energy efficiency results in more competitive and profitable Missouri agricultural products. The farmer together with the rest of society also benefits from improved environmental quality. Energy efficiency reduces the vulnerability of the farm sector and Missouri's economy to supply shortages and price spikes for imported fuels.

Missouri farmers have many technical opportunities to incorporate cost-effective technology improvements in farm operations and use energy more efficiently. These include opportunities related to irrigation, fertilizer use, farm vehicles and machinery and other energy-intensive operations. A valuable resource through which the state can assist farmers' efforts to take advantage of these opportunities is the land grant university system and Cooperative Extension Service. Together these provide a publicly funded, time-tested infrastructure for the development and transfer of improved agricultural technology.

Potential sources of financial assistance for innovative technology projects include the Missouri Department of Agriculture Sustainable Agriculture grant program and Alternative Loan Program. In addition, there have been proposals at the federal level that might provide other funding for voluntary farm energy audits and other efforts to increase the energy efficiency of farm enterprises.

Irrigation

Current and planned new irrigation of Missouri cropland occurs primarily in the Bootheel. Abundant water supply and predominantly hot, dry summer weather encourage irrigation in the area. The topography of the land and high water table permit the use of furrow (flooding) as well as central pivot systems. Like central pivot systems, furrow systems are energy-intensive since they require pumping water long distances

According to the most recent (2001) survey of irrigation in the Bootheel, furrow systems are currently more common (53 percent) than central pivot systems (47 percent); however 57 percent by acreage of planned new irrigation systems will be center pivot.

The predominant energy source used for irrigation in the Bootheel is diesel (47 percent of irrigated acreage). The remaining systems use electricity (30 percent of acreage) or propane (23 percent of acreage). Data on total energy use for irrigation is not available although it could probably be estimated using production budgets and expenditure data

²⁴ University of Missouri-Rolla Industries of Future web site <http://www.umsr.edu/~iac/iof/AG/biofuel.htm>

Cropland irrigation outside the Bootheel is limited primarily to two areas centered around Audrain and Benton counties. Of approximately 2.4 million acres of corn cultivated outside the Bootheel in 2000, only about 40,000 acres were irrigated. By comparison, in Nebraska, about 4.8 million acres of corn (60 percent of all acres) and 1.9 million acres of soybeans (40 percent of all acres) were sprinkler-irrigated in 2000.

Irrigation that does take place outside the Bootheel relies primarily on center pivot systems using diesel (45 percent), electricity (42 percent) or a combination of diesel and electricity (4 percent). Only about 9 percent of irrigation systems use propane.²⁵

Under current economic circumstances, it is unlikely that many new irrigation systems will be added in areas of Missouri outside the Bootheel. In four of the last five years, irrigation outside the Bootheel has failed to pay for itself.²⁶

No data is available on the energy efficiency of irrigation in Missouri. However, as a general rule, many irrigation systems in the United States are not as energy efficient as they might be. The Natural Resources Conservation Service (NRCS) *Irrigation Guide* summarizes the reasons as follows:

Many irrigation pumping installations were designed and installed when energy costs were lower. Typically, the original installation was not as efficient as those installed today. Some installations were poorly designed or improperly installed in the first place. Many pumping plants have not been maintained properly and have significantly lower efficiencies than when originally installed. Length of irrigation sets, and thus pumping times, is frequently governed more by the irrigator's schedule than by the needs of the crop. This leads to many pumping plant installations being much less efficient because of management than they could be.²⁷

The *Irrigation Guide* discusses a number of possible solutions including increases in pumping plant efficiency and irrigation efficiency, reduction of pressure requirements and proper irrigation scheduling.

Introduction of irrigation scheduling is one of the most cost-effective methods to reduce waste. The guide comments that "where the water supply is not limited, the greatest waste of water (and energy) is usually over-irrigation. Excess water application reduces plant yield or biomass, limits the ability of soil to grow crops, wastes nutrients, and increases the potential for surface or ground water pollution. In some areas, irrigation water managers use up to five times as much water as is needed. Even a simple program of irrigation scheduling can greatly reduce excessive use."²⁸ However, according to the 2001 Missouri Irrigation Survey, about 80 percent of irrigation systems in the Bootheel do not use an irrigation scheduling method such as the Arkansas Scheduler computer program or Woodruff irrigation charts. Those who do use a scheduling method achieve higher yields than those who do not.

²⁵ Fuel use data is based on averaging results from the most recent five years of Irrigation Surveys.

²⁶ Four of the five most recent Missouri Irrigation Survey reports on irrigation outside the Bootheel state that "additional yield attributed to irrigation was not enough to pay for the additional variable costs of irrigation."

²⁷ USDA/NRCS, *National Engineering Handbook*, Part 652, *Irrigation Guide*, Chapter 12, "Energy Use and Conservation" available at http://www.wcc.nrcs.usda.gov/nrcsirrig/Handbooks_Manuals/Part_652/part_652.html

²⁸ *Irrigation Guide*, p. 12-3

Improving irrigation system efficiency and scheduling has been a major programmatic focus for many plains and western states where energy-intensive center pivot irrigation systems are a major component of agriculture sector energy use. For example, the Idaho Department of Water Resources Energy Division has developed Scientific Irrigation Scheduling, pump efficiency testing, training and other programs for Idaho's irrigators.²⁹ The Northwest Energy Efficiency Alliance has funded an agricultural meteorological information system that is intended to help irrigators in the Pacific Northwest improve irrigation scheduling.³⁰ The Colorado Office of Energy Management has partnered with the Colorado Corn Administrative Committee, the U.S. Department of Agriculture (USDA)-Agricultural Research Service and a leading manufacturer of center pivot systems, to develop a "precision irrigation" system capable of decreasing electricity, natural gas and water use while increasing yields and improving health of the soil.

It seems likely that in Missouri, as in other states, irrigators could improve profitability while conserving energy and water resources by adopting scheduling and other efficiency measures. The state could assist these efforts through existing research, information and agricultural loan programs, focused technology transfer programs, and continued sponsorship of events such as the conference on irrigation technology that takes place annually in the Bootheel.

Fertilizer Use

Based on findings from other states, fertilizer use accounts for a large percentage of primary energy use by Missouri farmers. Agricultural inputs, especially fertilizer, typically embody two to three times the energy that is used directly on the farm.³¹ It has been estimated that fertilizer use accounts for 75 percent of primary energy use by farmers in Iowa.³²

The manufacture of N fertilizer is energy intensive and relies on natural gas as a source of both energy and chemical-reducing power to convert nitrogen gas from the air to ammonia. Ammonia is used to produce all other N fertilizers.

Production of a ton of solid ammonium nitrate, a fertilizer composed of 34 percent nitrogen, requires 22 million Btu of energy. Of this 22 million Btu, 82 percent of the energy is in the natural gas feedstock, 4 percent is used to produce the liquid nitric acid and 11 percent is used in the drying and granulation processes. For perspective, the energy used to make one ton of ammonium nitrate is equivalent to the energy in 176 gallons of gasoline.³³

The discussion of technical options for reducing nitrous oxide emissions from N fertilizer use estimated that Missouri farmers might be able to reduce N fertilizer use by 15 to 20 percent. To put this possibility into perspective, Iowa farmers reduced N fertilizer use on corn by an average of 15 percent from 1985 through 1995, reducing ground water pollution and decreasing production costs without significant declines in corn yields. This result was promoted by the

²⁹ <http://www.idwr.state.id.us/energy/AIM/ageff.htm>

³⁰ <http://www.nwalliance.org/projects/current/irrigsched.html>

³¹ Fluck, R.C. and C. D. Baird, *Agricultural Energy Consumption Patterns in the State of Florida*, 1990. This project was sponsored by the Florida Energy Extension Service.

³² EPA

³³ Fluck and Baird, op. cit.

Iowa Agricultural-Energy-Environmental Initiative. A cooperative program of the Iowa Department of Agriculture and Land Stewardship, Iowa State University, Practical Farmers of Iowa, the Iowa Department of Natural Resources and farmers in all 99 counties, the initiative utilized demonstrations, soil testing and other means to promote improved fertilizer management practices. The resulting cost savings have been estimated at more than \$460 million and the energy savings as equivalent to 614 million gallons of diesel fuel.

From a long-term perspective, fertilizer requirements could be substantially reduced by the development of new plant species. Geneticists at the University of Missouri have long participated in cooperative maize and soy genome research projects with researchers from other universities and USDA. Missouri researchers currently are pursuing a number of plant genome research projects funded by the National Science Foundation and other sources. This research might eventually develop hybrid grain crops that have some qualities of legumes including the ability to fix nitrogen.

Motorized Farm Vehicles

A large component of direct on-farm use of energy is diesel use in on-road vehicles such as trucks and off-road vehicles such as tractors and other specialized machinery.

While no data on farm vehicle maintenance in Missouri is available, the experience of other states is that routine maintenance practices for tractors and other farm machinery could be improved in many cases, resulting in more years of service at peak efficiency. MU Cooperative Extension publications regularly advise farmers to maintain regular engine service and other maintenance routines.³⁴ The Florida Energy Extension Service quotes “a major company service engineer” as saying that farmers “are getting about one-fourth to one-half the engine life that some major fleet operators get from engines [by following] a rigid schedule for maintenance and care.”

Routine maintenance of farm vehicles will likely pay for itself in fuel savings. A study of 50 farm tractors conducted by the University of Kansas Agricultural Experiment Station showed that the average farm tractor operates at less than 90 percent efficiency and uses 15 percent more fuel than necessary. A 40 to 60 horsepower diesel tractor uses 3.2 to 4.9 gallons of fuel per hour according to Nebraska tests. At this rate of fuel use, a 15 percent wastage rate would waste about 3 thousand gallons of diesel fuel (and cost about \$3,000) over a 5-year period.

Another method by which Missouri farmers can reduce fuel use and the costs associated with running and maintaining specialized off-road machinery is to adopt some form of conservation tillage. No-till systems reduce farm machinery fuel, maintenance and depreciation costs by about \$9.50 per acre.³⁵

³⁴ For example, University of Tennessee Agricultural Extension Service, *Farmer Decisions 2001: Farm Machinery and Equipment*, at <http://www.utextension.utk.edu/anr/equip.html>

³⁵ UMC Cooperative Extension Publication G355, “No-Tillage and Conservation Tillage: Economic Considerations”

Specialized Energy-Intensive Applications

There are many examples of specialized energy-intensive applications in agricultural operations in which it is possible to introduce new energy-efficient technologies that increase the profitability of the farm operation while reducing energy use. These include temperature and climate control in greenhouses, mechanized feeding in livestock operations, refrigeration and vacuum pumps in dairy operations and heating and ventilation in livestock buildings. Through the research and extension facilities centered in its university system, Missouri can continue to develop and promote energy-efficient technology in these applications.

There are many examples of research that have developed and demonstrated changes in practice that increase energy efficiency, improve production and save money. For example, researchers affiliated with the Florida Energy Extension Service demonstrated that the prevailing rule of thumb for sizing vacuum system capacity in milking machines was excessive.³⁶ An Iowa Energy Center research project found that changing to larger, highly efficient heat lamps in farrowing facilities would reduce energy costs and increase production.³⁷

The state's potential role in introducing new technology is exemplified by research at Iowa State University that led to the development of a computerized natural ventilation controller for livestock buildings. The controller provides a low-energy alternative to mechanical ventilation while allowing naturally ventilated buildings to maintain their temperatures within two degrees of optimum conditions and improving the internal air quality of the facilities. This new technology was named one of the Top Ten New Products at the 1996 Iowa Pork Congress. Funding to develop this new technology was provided by the Iowa Energy Center.

Opportunities to Reduce GHG Emissions Through Renewable Energy Development in Missouri's Agricultural and Forestry Sectors

Missouri's farms and forests represent a vast reservoir of potential renewable energy resources. Development of these resources could diversify and reduce Missouri's reliance on imported fossil fuels for energy, reduce emissions of air pollutants including CO₂ that result from fossil combustion and fossil-fired electric generation and provide new income streams to farmers and rural landowners.

It is a generally accepted practice to attribute zero GHG emissions to wind, biomass and solar energy use. The case of biomass requires some explanation since biomass combustion undoubtedly leads to emissions of CO₂ as well as NO_x and possibly other pollutants. It is a generally accepted practice to consider that combustion of biomass resources such as wood and energy crops results in zero net CO₂ emissions. CO₂ is emitted when biomass is burned but it is assumed to be recycled by new plant growth.

The CO₂ reduction that can be credited for use of renewable energy resources, including electric generation from renewables, depends on the CO₂ emissions rate of the fuel or source of the generation that is being displaced. For electric generation from a renewable resource such as

³⁶ Florida Energy Extension Service, <http://edis.ifas.ufl.edu/scripts/EH174>

³⁷ Iowa Energy Center,

wind, solar or co-fired biomass, a good rule of thumb is that two pounds of CO₂ are displaced for each kilowatt generated.

Other benefits of renewable energy development include a large economic multiplier effect from renewable installations and increased diversity of energy supply. It has been argued that employment benefits would occur, because construction and operation of renewable energy projects generate more jobs than does a comparably sized fossil fuel plant.³⁸ Greater use of Missouri's indigenous renewable energy resources would help to insulate the state from fossil fuel price shocks and supply disruptions.

In most cases, in addition to CO₂ reduction there are potential air and water benefits from using renewable energy resources rather than fossil fuel-based energy. The environmental impact of biomass energy use must be analyzed on a technology- or case-specific basis. Biomass combustion typically results in emissions of NO_x and other pollutants and biomass-based methane production may result in other waste streams. In analyzing the environmental impact of particular biomass applications it is necessary to consult the growing technical literature that discusses the emissions characteristics of various biomass-based energy technologies.

Opportunities for Using Biomass from Missouri Farms and Forests

Missouri's agricultural and forest sectors have substantial biomass energy resources that are unused or under-utilized. A 1997 study estimated the total energy content of selected state biomass resources at about 410 trillion Btu.³⁹

More than 90 percent of the biomass resources covered by this inventory derive from the agricultural sector or the forest sector. Agricultural sector resources include crop residues and energy crops that could be potentially produced on idle Conservation Reserve Program (CRP) lands. Forest resources include wood residues from logging and wood residues from primary wood processing.

Agricultural and forest biomass energy resources not covered by this inventory include standing timber, animal waste and methane from livestock manure management systems. The report did not include standing timber because quantification of that resource is done periodically by the U.S. Forest Service.

The Governor's "One Missouri" Agriculture Task Force⁴⁰ identified renewable biomass as one of several new agricultural product categories that the state should promote and for which the state should provide incentives. Renewable biomass has a number of attractive features, including the possibility of growing it on land not suitable for crops that require intensive

³⁸ *Hawaii Energy Strategy*, Chapter 2, Project 3, March 1998. Because there is great variation among renewable energy installations, this proposition would need to be verified on an individual case basis when determining whether to pursue a specific project.

³⁹ Van Dyne, Don and Mel Blase, *Estimated Volume and Energy Content of Biomass and Municipal Solid Waste Resources in Missouri*, Department of Natural Resources' Energy Center and University of Missouri, 1997. Hereafter cited as *Biomass Resources in Missouri*.

⁴⁰ Governor's Task Force on Agriculture 2001, *One Missouri, One Agriculture*, Jefferson City, Missouri, December 2001. Hereafter referred to as the Governor's "One Missouri" Agriculture Task Force.

agricultural methods. For example, with changes in program requirements, switchgrass might be cultivated on CRP land.

Cultivation of switchgrass and other energy crops using conservation tillage methods offers many benefits described later in this chapter. Among other benefits, CO₂ emissions are reduced in three different ways:

1. When renewable biomass is used as an energy source, net atmospheric CO₂ is not increased because CO₂ emitted when the biomass is burned is reused when the next biomass crop is cultivated. In contrast, when fossil fuels are used as an energy source, net atmospheric CO₂ is increased.
2. Intensive tillage methods require combustion of diesel fuel to operate farm machinery. A reduction in tillage reduces these energy use requirements and thereby decreases CO₂ emissions from fuel use. The greatest gain comes from no-till methods.
3. Because conservation tillage leaves residue on the ground, soil carbon increases and more carbon is sequestered from the atmosphere.

Opportunities for Direct Use of the Heat Content of Biomass

Firewood has long been the dominant form in which biomass resources are used for heating in Missouri. The *1990 Inventory* estimated that in 1990, firewood provided 27.8 trillion Btu of energy to Missouri homes. Assuming that the wood displaced natural gas, the leading source for home heating in Missouri, this level of wood use avoided about 1.6 million tons of CO₂ emissions. However, the use of firewood as a heating source in Missouri has declined steadily since 1990.

A variety of technologies for directly using heat content of waste biomass from forest and agricultural sources are being used and demonstrated at Northwest Missouri State University, a regional institution whose campus includes over 1.7 million square feet of building space. The campus is located in Maryville, a town of 11,000 in a mostly rural area of Missouri.

Over the past two decades, beginning in 1978, the university has increasingly shifted to using biomass resources to meet campus heating needs.⁴¹ Today, having weaned itself from reliance on petroleum-based fuels (natural gas and heating oil) purchased out of state, the university saves an average of \$375,000 a year by burning alternative fuels (wood chips and pelletized paper) from sources found in Missouri and adjacent states. Reliance on biomass for heating also provided the impetus for a campus-wide comprehensive recycling program. Recently, the university incorporated into its fuel mix pelletized animal waste from its animal husbandry programs.

Wood chips from forest products industry waste provide approximately 65 percent of the university's thermal energy needs. Combustion of wood chips provides the university with a steam capacity of 25,000 pounds per hour. The university's demand for wood chips created a

⁴¹ Courter, Raymond J. and Nancy S. Baxter, *Significant Savings Gained From the Utilization of Alternative Fuels at Northwest Missouri State University*, <http://www.nwmissouri.edu/sloan/CostBook/AlternativeFuels.html>

new market for wood waste by-products that stimulated a number of wood chip suppliers to go into business.

The paper component comes from clean waste paper formerly deposited in the landfill. The waste paper is diverted to the university and converted into dense pellets as a source of energy. The decision to use waste paper came after determining that transporting waste paper to regional recycling centers located over 100 miles away was not cost-effective.

Recently, the university has built an addition onto its existing pellet processing facility (known as the Biomass Processing Center) to add a second production line dedicated to producing biomass fuels from a variety of agricultural and agribusiness waste resources. Animal waste from a newly designed swine facility and dairy operation is separated into liquid and solid components. The solids are mixed with dry agricultural feedstocks and the virtually odor-free dry mixture is transported to the processing facility for pelletization into an energy fuel source.

The university intends to demonstrate this unique resource recovery approach and provide technical assistance to regional farm operators, business representatives and industry leaders who are seeking to improve their economies by more efficiently using or processing their waste.

Opportunities for Electric Generation from Biomass

The size of a given biomass power installation historically has been limited by low efficiencies and the amount of fuel within an economical transportation radius. The resulting low output yields a high capital cost for these systems. Recent technological developments promise to reduce or remove these constraints to the biomass power option.

Biomass gasification technologies currently being developed could nearly double current biomass electrical generation efficiencies. Biomass generation options will continue to expand as a result of technological advances being made by government and industry-funded gas turbine and fuel cell development programs.

Technological advances are also addressing the fuel requirement barrier. Use of advanced combined-cycle technology reduces fuel requirements because of the striking increase in generating efficiency. The amount of biomass supply required to enjoy the benefits of high efficiency generation will be further reduced by the deployment of smaller, industrial-scale, gas turbines with very high efficiencies that are being developed under the U.S. DOE's Advanced Turbine System program.

Despite these technological advances, it is not likely that biomass-based power plants will be able to compete head-to-head any time soon with centralized power generation based on other technologies. According to a recent National Renewable Energy Laboratory (NREL) study, “even the most promising electricity cost from biomass is higher than currently quoted avoided costs and new, high-efficiency natural gas combined cycle systems.”⁴²

Instead, biomass generation is likely to serve specific markets and situations as part of Missouri's distributed generation resources or through co-firing.

⁴² Kevin R. Craig and Margaret K. Mann, Cost and Performance Analysis of Three Integrated Biomass Gasification Combined Cycle Power Systems

The most plausible role for biomass in centralized utility generation is probably the implementation of co-firing. Co-firing makes it feasible to use biomass in a large centralized plant that could not rely exclusively on biomass because it would be too costly to transport sufficient biomass feedstocks from the wide area required to support the plant.

One promising biomass feedstock readily grown in Missouri is switchgrass. According to the *Biomass Resources in Missouri* study, substantial quantities of switchgrass could be cultivated on CRP land in Missouri as a supplementary fuel for a centralized plant located in the same geographic region.

Alliant Energy is currently testing switchgrass co-firing at their 650 megawatt coal-fired Ottumwa generating plant, located in Iowa close to the Missouri border. The project, begun in November 2000, will test the impact on the boiler's efficiency of replacing up to 5 percent of the coal burned in the plant with switchgrass. Bales of switchgrass, resembling bales of straw, are fed by conveyor into a machine that chops and grinds them into a dust that is blown into the furnace. Approximately 100 farmers are growing switchgrass for the Iowa plant. Jerry Schnoor, co-director of the University of Iowa's Center for Global and Regional Environmental Research, has estimated that carbon dioxide emissions could be cut by nearly 177,000 tons per year and emissions of sulfur dioxide by as much as 113 tons per year if 5 percent of the coal were replaced with switchgrass. (Washington Post, Promising Fuel Crops Up for an Iowa Utility, 02/10/01, p. A02).

Of special interest is biomass reburn co-firing, due to its impact on both NO_x and CO₂ emissions. In this technology, which is currently being demonstrated using U.S. DOE grant money, gasified biomass takes the place of natural gas in the reburn process. There is an upper limit to how much biomass can be used for co-firing, but due to the very large contribution of coal-fired plants to GHG emissions, the substitution of biomass for even a small percentage of coal burned in power plants could have a significant impact on total GHG emissions.

Although co-firing reduces supply requirements, the successful use of biomass for co-firing still requires a system for assuring that a reliable supply of biomass is available and transporting it to the power plant. U.S. DOE, NREL and ORNL are pursuing the development and demonstration of Dedicated Feedstock Supply Systems (DFSS). DFSS are intended to sustainably supply larger quantities of biomass feedstock than were heretofore available.

Opportunities to Substitute Agricultural or Forestry Biomass-Based Fuels and Products for Petrochemical Fuels and Products

The two main substitutes for fossil fuels now produced in the United States from agricultural products are ethanol and biodiesel, both of which are used primarily for transportation. The use of ethanol and biodiesel reduces CO₂ emissions from transportation compared to the use of gasoline and diesel. Their greenhouse gas impact is further discussed with other “alternative” transportation fuels in the Transportation chapter.

The National Biodiesel Board estimates that about 500 thousand gallons of biodiesel fuel were produced in the United States in 1999, 5 million gallons in 2000 and 10 to 15 million gallons in 2001.⁴³ No biodiesel is currently produced in Missouri.

Over 1.5 billion gallons of ethanol are added to gasoline in the United States each year. Two Missouri plants currently produce ethanol from corn. Northeast Missouri Grain Processors opened the first plant in April 2000 and Golden Triangle Energy Cooperative opened a second plant in February 2001. Their combined capacity is about 39 million gallons.

At present, most U.S. production of biodiesel is from soy and most U.S. ethanol production is from corn. However, biodiesel can also be produced from other vegetable oils such as canola and rapeseed oil, animal fats and recycled greases. Similarly, ethanol can be produced from a variety of agriculture- and food-derived wastes such as potato waste and cheese whey and from ligno-cellulosic biomass.

Production of ethanol from corn is a well-established process and the market for ethanol produced from corn is increasing. However, several economic factors ultimately limit ethanol production from corn. First, ethanol produced from corn is not price-competitive with gasoline without some form of continued government subsidy. Second, there is an upper limit to the amount of corn ethanol, estimated by most analysts as 3 to 5 billion gallons that can be produced without severely disrupting traditional food and feed markets. Expansion of corn production to marginal cropland could have adverse economic and environmental impacts.⁴⁴

Missouri has an abundance of ligno-cellulosic feedstocks (LCF) that could be used for LCF ethanol production complementing production from corn. These include wood waste, agriculture residues, the paper component of municipal solid waste, and the potential to cultivate fast-growing grasses such as switchgrass and fast-growing trees such as poplars.

Production of ethanol from LCF is at an early stage of commercial development in the United States, with plants having been established by BC International and Masada Resources Group.⁴⁵ The federal ethanol tax credit includes ethanol produced from LCF. There have been continued technological advances in developing the biomass-to-ethanol conversion process. Advances in designing DFSS for electric generation from biomass could also apply to feedstock supply for production of ethanol and other products from biomass.

To be commercially viable, LCF ethanol production in Missouri probably needs to be approached as part of an integrated process delivering new products manufactured from Missouri's agricultural and forestry sector. In 1998, University of Missouri researchers studying the economic feasibility of producing ethanol from crop residues and other biomass feedstocks in Missouri concluded that the key to profitability would be identifying, manufacturing and marketing chemical co-products such as furfural, a feedstock used by the plastics industry. The

⁴³ Personal communication, National Biodiesel Board, March 5, 2002

⁴⁴ Van Dyne, Don, Michael Kaylen and Melvin Blase, *The Economic Feasibility of Converting Ligno-Cellulosic Feedstocks into Ethanol and Higher Value Chemicals*, UMC Department of Agricultural Economics, June 1998, p. 3

⁴⁵ More information is provided by the companies' web site, <http://www.bcintlcorp.com/> and <http://www.masada.com/>

study concluded that at current prices, production of ethanol from biomass would only be profitable if it were co-produced with other higher value products in a ‘biomass refinery plant.’”⁴⁶

More broadly, biofuel development could be considered an integral part of an effort to develop a new industry, parallel to the petrochemical industry, capable of delivering a variety of new products derived from agricultural and forestry products and wastes rather than imported fossil fuels. Scientific and commercial breakthroughs are being pursued to develop such an industry. An analysis of opportunities and obstacles by U.S. DOE’s Office of Industrial Technology concludes that “with further development of new thermal, chemical and biological processes, there are opportunities to expand the use of plant-based renewables in economically viable systems.”⁴⁷

Development of a new biomass refining industry parallel to the petrochemical industry would fit well with recommendations of the Governor’s “One Missouri” Agriculture Task Force. The task force calls for agriculture to develop a “game plan” to expand the life sciences infrastructure to maximize the potential for marketing Missouri agricultural products. As that report indicates, Missouri has designated life sciences as a lead industry for state economic development. Missouri is home to a number of world-class research institutions, nationally ranked teaching hospitals and biotech research corporations and, thus, is well positioned to take a leading role and profit from the development of new biomass-based industries and products.

Opportunities for Farm-Based Wind Generation

Electric generation from wind, as from other renewable energy resources, reduces CO₂ emissions that would otherwise occur by displacing generation from fossil fuel. Wind resources can be used with both large wind turbines for utility applications and small wind turbines for on-site generation.

Opportunities for On-Site Generation

Individually-owned wind turbines are more likely to be practical in rural than urban areas of Missouri, since most of the main wind turbine manufacturers say customers need at least one acre of land and urban areas are more likely to impose height restrictions. Wind turbines are most likely to generate power efficiently at heights well above 35 feet to provide a clear wind path free of obstructions such as trees and buildings.

Several wind turbine installations exist in rural Missouri, primarily serving owners who have decided, due to their remote location or for other reasons, not to connect to the electric grid.

The up-front investment required for a typical small 3 kW wind turbine system is about \$32,000. In California, where substantial state rebate payments are available, it is estimated that a 3 kW

⁴⁶ Van Dyne, *The Economic Feasibility of Converting Ligno-Cellulosic Feedstocks*, 1998, previously cited

⁴⁷ DOE/OIT, *Plant/Crop-Based Renewable Resources 2020: A Vision To Enhance U.S. Economic Security Through Renewable Plant/Crop- Based Resource Use*”

turbine with wind speeds averaging 10 to 12 miles per hour would decrease the electricity bills by \$50 to \$200 per month and have a 5 to 10 year payback.⁴⁸

A similar system installed in Missouri would face a longer payback period because electricity rates in Missouri are lower than in California and state rebates are not available.

Opportunities for Utility-Scale Generation

Wind power has become the fastest growing sector of the electric utility industry in the United States and worldwide. In part this is due to substantial improvements in the technology of wind energy over the past 20 years, including improved reliability (availability factor), higher conversion efficiency (more power per square meter of swept area), taller towers (improved exposure at higher altitudes) and larger turbines (yielding improved economy of scale). Advances in wind turbine components including airfoils developed specifically for wind turbines, innovative variable- or low-speed generators, new types of rotors and advanced control systems that are responsive to complex operating environments, make it possible to generate power at .5 cents per kilowatt-hour in 15 mile per hour winds. Thus, it is now possible to profitably operate wind farms on areas with a wind resource that 10 years ago were considered sub-marginal for utility scale wind development.

Portions of rural Missouri may have a sufficiently strong and reliable wind resource to support the development of “wind farms” based on a series of turbines tied into the electric grid. “Wind farms” have long been common in Europe. Recent announcements of large commercial wind farm ventures indicate that a combination of technological advances and marketplace changes has strengthened the suitability and attractiveness of utility-scale centralized wind farms.⁴⁹ The model that is probably more suitable to Missouri is a smaller wind farm with turbines positioned on adjacent sites within a localized “cell” of high-quality wind resources. Wind farms on this model have been constructed in a number of states including Iowa, Minnesota and Wisconsin. They are now being developed in Illinois following the recent determination that sufficient wind resources to support them exist in localized “cells” scattered through rural counties in the state.

The concept of wind farms has attracted great interest from Illinois farmers who hope to profit from leasing land to independent power producers (IPPs) or developing cooperatively-owned wind farms as farmer-controlled business ventures. A typical turbine requires about a quarter-acre of land for the site and an access road, and the land around the sites can continue to be farmed. A typical lease to an IPP generates an annual income of \$2,000 to \$5,000 per site.

There is reason to believe that rural Missouri has localized wind resources, resulting from terrain and meteorological effects that are sufficient to support profitable utility-scale ‘wind farms.’ For example, in 2000, a wind study conducted in Nodaway County confirmed a solid class three wind resource near the town of Elmo, Missouri. However, isolated wind studies will not be sufficient to develop the momentum necessary to accurately estimate and effectively use

⁴⁸ *Producing Winds of Change: as power prices rise, windmills are one way to decrease costs*, SF Chronicle February 27, 2001

⁴⁹ “Wind farm to supply 11 western states,” AP, Thursday, January 11, 2001; “As demands for energy multiply, windmill farms stage comeback,” Wall Street Journal, January 26, 2001. Also see

Missouri's wind resources. An accurate and detailed map of Missouri's wind resources will be required to develop the necessary momentum.

Detailed wind maps accelerate the initial stages of wind project development, and substantially reduce the barriers to entry for new project developers. High-resolution maps allow wind project developers to expeditiously and accurately identify the most productive wind features in the state and complete an initial screening of many possible sites in a short amount of time. Without detailed maps, identifying promising sites is an expensive, risky "hit or miss" process.

The only currently available wind map for Missouri is a low-resolution map published by U.S. DOE as part of the *Wind Energy Resource Atlas of the United States*.⁵⁰ This map, compiled in 1987, indicates that over 90 percent of Missouri's land area has class one or two wind resources. A few areas are shown to contain class three wind resources.⁵¹ The 1987 wind maps were completed using a resolution of 25 square kilometers. At this low resolution, the 1987 map provides only a gross indication of general areas with potentially productive wind sites.

In 1993, the Union of Concerned Scientists (UCS) developed an alternative estimate of Missouri's wind energy potential in the publication *Powering the Midwest*. The UCS study estimated Missouri's wind energy potential as 8,293 MW (peak) or 19,149 million kWh (annual) at less than six cents per kilowatt-hour. The UCS study indicated that the Ozark Plateau, running roughly from Joplin, MO, to Rolla, MO, and small areas along the Missouri-Iowa border, were identified as the areas most likely to hold developable wind resources. However, the UCS study did not include the detailed maps that would be required to develop these resources.⁵²

Significant wind generation, whether utility scale or on-site "distributed" generation, is not likely to occur in Missouri until reliable high-resolution maps of the state's wind resource are available. Progress in the modeling of wind energy has resulted in lowering the cost of analysis, reducing the time required, and improving the resolution and reliability of the work products. Considering all factors, a project to prepare new wind resource maps covering Missouri, prepared on a 400-meter grid at multiple elevations, would be appropriate.

The likelihood that a high-resolution map would reveal high-quality wind resources in Missouri is demonstrated by the Illinois experience. Until recently, only a low-resolution wind map was available for Illinois. The 1987 Illinois wind map was similar to the 1987 Missouri map in that it indicated that the state's wind resources were primarily class two, with about 20 percent of the land area in class three, but no class four wind.

In 2001, NREL completed a new high-resolution wind map, based on cells of 1 square kilometer that indicated Illinois has a class four wind resource capable of supporting 3,000 megawatts of

⁵⁰ See NREL's Wind Energy Resource Atlas of the United States, available at: <http://rredc.nrel.gov/wind/pubs/atlas/maps/chap3/3-15m.html>.

⁵¹ Wind resources are divided into seven wind power classes based upon the average wind speed. Wind classes three (minimum average wind speed of 14.3 miles per hour at 50 meters height) and higher are commonly accepted as the amount of wind needed to realize an economically feasible wind energy project.

⁵² UCS's estimate for Missouri cannot be directly confirmed because no independent wind potential assessment has been done for Missouri. However, an independent assessment for the state of Minnesota concluded that the UCS estimate for Minnesota, if anything, underestimated wind potential for that state. Personal communication, Rory Artig, Minnesota Energy Office

utility scale wind development. The new map identified the best locations for wind generation in cells covering just 0.4 percent of the state's land area. The cells were located southeast of Quincy covering parts of Adams and Pike counties, McLean County just northwest of Bloomington and along a corridor running north from Peoria to the junction of Bureau, LaSalle and Lee counties. All these cells were shown to have sustained class four wind ranging from 15.7 to 16.4 mph.

Opportunities for Farm-Based Solar Energy Use

Currently, the most cost-effective technologies for using solar energy in Missouri's rural areas are passive solar applications and the use of photovoltaic (PV) technologies for niche applications.

Passive Solar Applications

Rural Missourians have many opportunities to take advantage of cost-effective passive solar applications in farm residences as well as agricultural operations. There are well-established principles for optimal passive solar building design that can be applied either to the rural residence or the agricultural operation. A number of MU Cooperative Extension publications directed to Missouri's rural and farm-based population describe these principles and how they may be applied to rural homes⁵³ and farm buildings.⁵⁴

For the many rural households in Missouri that use electricity for water heating, the addition of solar hot water heating at the front end of the electric heater can be a practical way to reduce the long-term energy bill. An average Missouri⁵⁵ household with an electric water heater uses about 3,000 kWh and spends about 25 percent of its home energy budget for hot water heating. Installing a solar water heater at the front end of the existing electric water heater could reduce the household's use of electricity for water heating by 60 percent, or 1,800 kWh per year. Following a 4-5 year payback period, homeowners would accrue savings over the remaining life of the system. System lifetime would range from 15 to 40 years, depending on the system and how well it is maintained.⁵⁶

Installation of solar hot water heating systems in 100 rural residences would reduce requirements for installed generating capacity by about 25 kW. In addition, CO₂ emissions would be reduced by about 180 tons per year, NO_x emissions by about 1,400 pounds per year and SO₂ emissions by about 2,100 pounds per year.

To date, passive solar hot water heating in Missouri has been confined primarily to residential applications. However, another possible application for solar hot water heating is to serve the

⁵³ For example, UMC Cooperative Extension Publications G1799 "Solar-Heated New Technology House," GH2100 "Managing Interiors for Energy Control" and GH5983 "Energy Management Checklist for the Home."

⁵⁴ For example, UMC Cooperative Extension Publications G01972 "Saving Energy with Passive Systems," G1971 "Active Solar Collectors for Farm Buildings" and MW23 "Solar Livestock Housing Handbook."

⁵⁵ These estimates are based on average for Missouri's climate zone. Actual hot water use varies due to a variety of factors including variation in climate within the state.

⁵⁶ The cost effectiveness substituting passive solar water heating for propane heating has not been analyzed. Propane prices in Missouri are much more volatile than electricity prices. Some rural homeowners might consider propane price volatility to be an additional factor that favors installing a supplemental passive solar hot water heater.

need of livestock operations for hot water. A hot water heater intended for this application would need to be designed to prevent freezing during Missouri's cold winter months. There are a number of ways that the design requirements might be achieved. This should be considered a potential niche market that could be profitable for installers as well as users of the systems.

Other opportunities for Missouri agricultural operations to take advantage of the energy cost savings inherent in passive solar design include grain drying and advanced greenhouse designs. As described in MU Cooperative Extension Service bulletins,⁵⁷ passive solar design can also help reduce the cost of grain drying.

Passive solar greenhouses are already successfully used in Missouri and forthcoming design improvements promise to increase their profitability and extend their utility. For example, in a four-year project, MU Cooperative Extension Service horticulturists are cooperating with Kansas State University researchers and growers in Missouri and Kansas to determine the efficacy of "high tunnels," a passive-solar greenhouse design. The system promises to provide a low-cost, highly profitable method for growing vegetables in the Midwest that can extend the growing season of vegetable crops into winter months.⁵⁸

A significant increase in the share of winter produce supplied by passive solar greenhouses in Missouri could reduce direct energy consumption for growing produce as well as transportation fuel use required to truck winter produce into Missouri from other states. Such a development could also contribute to the "Buy Missouri" campaign proposed by the Governor's "One Missouri" Agriculture Task Force.

Promotion of increased use of passive solar designs and increased energy efficiency could represent a cost-effective way for rural electric distributing companies to limit expensive investments required to expand electric generating or distribution capacity. Electric distribution cooperatives might identify opportunities to provide new, valuable services to their members. Particular programs would need to be designed based on the distributing company's knowledge of typical electricity use in the service territory and technologies and services that are locally available.

Niche Agricultural Applications for Photovoltaic Generation

PV technologies, which directly convert sunlight into electricity, utilize semi-conducting materials. Centralized utility-scale generation from PV arrays is currently much more expensive than other generating technologies due to the high cost of semi-conducting materials. Cost-effective distributed applications for PV generation include building-integrated PV or meeting power needs in remote locations. In grid-connected applications, PV generation of electricity is currently too expensive to compete effectively with power supplied from a central power station. However, PV generation does have a role in niche agricultural applications such as supplying electric power needs in a remote location where the cost of installing electric power lines is prohibitive.

⁵⁷ UMC Cooperative Extension Bulletins MW22, Low Temperature and Solar Grain Drying Handbook and G1310 Low Temperature, In-Bin Drying: Shelled Corn.

⁵⁸ UMC College of Agriculture, Food and Natural Resources Press Release, "Great Plains Vegetable Conference in St. Joseph," <http://cafnr.missouri.edu/news/2001/1201/vegconference.htm>

For example, using PV to pump water for livestock in remote pasture areas can be a cost-effective and reliable method of placing the water supply where it is needed. One example of a well-designed remote site PV pump is a demonstration project in Osceola County, Florida that yielded up to 10 gallons per minute under peak sunshine and supplied the water needs of a herd of 30 pregnant cows. Total cost of the PV array was about \$2,000. A document published by the Florida Energy Extension Service describes this project in greater detail and discusses factors to be considered in evaluating a PV remote pumping project.⁵⁹

The MU Cooperative Extension Service has published a detailed explanation of how to design and determine requirements for a PV water pumping system for grazing livestock⁶⁰

Other typical agricultural PV niche applications include electric fences⁶¹ and greenhouse controls and vent fans.

Opportunities to Offset GHG Emissions by Sequestering Carbon in Missouri Forests and Agricultural Soil

Based on estimates by this project, Missouri forests and croplands are already sequestering substantial quantities of carbon that might otherwise enter the atmosphere as CO₂. The *Trends and Projections Report* estimates that in 2000, the growth of woody biomass in Missouri forests sequestered the equivalent of 24.8 to 25.2 million tons of CO₂ (STCDE). It is also estimated that an additional 1.7 million tons of CO₂ (STCDE) were sequestered by Missouri croplands due to the use of conservation tillage.

As described in this chapter, soil conservation and sustainable forestry practices can perpetuate and increase this level of sequestration while providing other economic and environmental benefits to farmers, rural landowners and all Missourians.

Overview of Carbon Sequestration

A *carbon sink* is a process or an activity that removes a greenhouse gas from the atmosphere. For example, forests and agricultural soil can serve as carbon sinks, reducing atmospheric concentrations of carbon dioxide by removing CO₂ from the atmosphere and storing it in a terrestrial ecosystem.

In original use, the term *carbon pool* referred to the total amount of carbon in a specific part of the ecosystem – for example, the soil carbon pool, the woody biomass pool in trees and roots, or the dead litter pool on the forest floor. Total carbon in an ecosystem equals the sum of carbon in these separate pools.

The term carbon pool has been extended in an effort to deal with carbon that leaves the ecosystem but may remain sequestered from the atmosphere for many years. Several recent

⁵⁹ Florida Energy Extension Service, http://edis.ifas.ufl.edu/scripts/MENU_AGLIVE

⁶⁰ UMC Cooperative Extension Bulletin EQ380, “Pumps and Watering Systems for Managed Beef Grazing,” Example 3.

⁶¹ Solar-powered fence energizers are described in UMC Cooperative Extension Bulletin EQ379, “Managed Grazing Systems and Fencing for Distribution of Beef Manure.”

studies of the role of forests and wood products in the carbon cycle at a national or global level have defined a sequence of “carbon pools” through which harvested carbon passes once it has left the ecosystem.

For example, when wood is harvested and used as timber for a building, carbon remains sequestered and is considered to be in the “product pool.” If the building is torn down, much of the carbon may remain sequestered. If the timber goes to a municipal or demolition landfill, the carbon is considered to be in the “landfill pool.” Only after all the carbon is released, when the timber totally decays or is burned, does the carbon leave this series of carbon pools.

A recent study by Kenneth Skog concludes that,

Since 1910, an estimated 2.7 Pg (petagrams; $\times 10^9$ metric tons) of carbon have accumulated and currently reside in wood and paper products in use and in dumps and landfills, including net imports. This is notable compared with the current inventory of carbon in forest trees (13.8 Pg) and forest soils (24.7 Pg). On a yearly basis, net sequestration of carbon in U.S. wood and paper products ... is projected to increase ... while net additions (sequestration) in forests is projected to decrease ... Net sequestration is increasing in products and landfills because of an increase in wood consumption and a decrease in decay in landfills compared with phased-out dumps.⁶²

U.S. EPA and U.S. DOE/Energy Information Administration have adopted this approach in recent national GHG inventories completed since 1998.

Carbon Sequestration in Missouri Forests

This conceptual framework is theoretically appealing and will be used in some discussions in this report. However, as was explained in detail in the *Trends and Projections Report*, the data and models required to estimate carbon in these various pools is not available at the state level. Therefore, the *Trends and Projections Report* estimated net forest carbon sequestration by using the simpler, less conceptually accurate but less-data intensive methodology provided by U.S. EPA's *State Workbook*. This methodology assumes that when biomass is removed from forests, all carbon contained in the biomass leaves sequestration and returns to the atmosphere.

Table 6 summarizes the *Trends and Projections Report's* estimates of sequestration by Missouri forests through 1996. The report projected that sequestration in 2015 would decrease to about 21.5 to 23.5 million tons STCDE. This however does not take into account sequestration in forest product pools.

⁶² Kenneth E. Skog and Geri Nicholson, “Carbon Cycling through Wood Products: The Role of Wood and Paper Products in Carbon Sequestration,” revised April 1998, prepared for publication in *Forest Products Journal*, p. 1. See also Heath, L.S., R.A. Birdsey, C. Row, and A.J. Plantinga. 1996. “Carbon pools and fluxes in U.S. forest products.” p. 271–278. In Proceedings of the NATO advanced research workshop. “*The role of global forest ecosystems and forest resource management in the global cycle.*” Banff, Canada. 12–14 Sept. 1994. NATO ASI Series I: Global Environmental Change. Vol. 40. Springer-Verlag, Berlin.

Table 6: Estimated Carbon Sequestration by Missouri Forests, 1990-1996

Units: 1,000 Tons Carbon Dioxide (CO₂)

	1990	1991	1992	1993	1994	1995	1996
Potential sequestration	34,615.00	34,615.00	34,615.00	34,615.00	34,615.00	34,615.00	34,615.00
Removals	7,541.00	7,654.48	7,953.62	8,255.90	8,558.79	8,726.38	8,882.91
Net sequestration	27,074.00	26,960.52	26,661.38	26,359.10	26,056.21	25,888.62	25,732.09

The *Trends and Projections Report* lists a number of factors due to which these estimates might overestimate or underestimate actual sequestration. These factors are included as Appendix 2.

Carbon Sequestration in Agricultural Soil

The long-term conversion of grassland and forestland to cropland and grazing lands, which has occurred not only in Missouri but throughout the world, has resulted in historic losses of soil carbon. However, this historic loss of carbon provides a major potential for increasing soil carbon through restoration of degraded soils and widespread adoption of soil conservation practices. USDA estimates that the total carbon sequestration potential of U.S. cropland is 154 million metric tons of carbon per year, equivalent to removing 622 million short tons of CO₂ (STCDE) from the atmosphere.⁶³

The principal strategies that sequester carbon also tend to reduce soil erosion, improve soil quality, increase the organic matter content of soils, improve wildlife habitat and contribute to sustainable land use. These include the following soil conservation practices:

- Adopting conservation tillage, discussed in the following section.
- Adopting other strategies for sustainable management of the soil such as the application of organic materials and manures, site-specific soil management to optimize fertility, elimination of summer (bare) fallow and use of winter cover crops and rotations.
- Removing agriculturally marginal land from production and managing it through a conservation program, for example, converting marginal cropland to wildlife habitat could lead to increases in total biomass production and an increase in carbon content in the soil.
- Agroforestry practices that increase carbon sequestration include the use of windbreaks, which store carbon while protecting farmsteads, livestock, roads, people, soils and crops; use of riparian forest buffers that store carbon while protecting water quality; use of silvopasture which stores carbon while producing livestock benefits if both trees and grass are properly managed; and planting of short-rotation woody crops which store carbon while providing income from wood products or biofuel.
- Managing land under guidelines of USDA conservation programs such as the Conservation Reserve Program (CRP), the Wetland Reserve Program (WRP), the Stewardship Incentive Program (SIP), Forestry Incentives Program (FIP) and the USDA Secretary's conservation buffer strip initiative.

⁶³ <http://www.usda.gov/oce/gcpo/sequeste.htm>

Follett, Lal and others have estimated the impact of several “best management practices” on soil carbon sequestration rates.⁶⁴ Table 7 presents some of these results, converted from kilograms of carbon sequestered per hectare per year to pounds of CO₂ sequestered per acre per year.

Table 7 – Estimated Soil Carbon Sequestration from Selected “Best Management” Practices

	CO ₂ sequestered (pounds per acre per year)	
	Low	High
Livestock management		
Improved pastureland management	164	491
Improved grazing management	982	4,256
Increases in plant foliage		
Commercial fertilizer applications	327	655
Manure applications	655	1,637
Use of improved plant species	327	982
Soil restoration		
Restoration of eroded soils	164	655
Restoration of mined lands	3,274	9,821

Empirical studies for Iowa, Montana and the United States have estimated a marginal cost for sequestering carbon in soil ranging from near zero to hundreds of dollars per ton, depending on how much carbon must be sequestered through these methods alone. The US-wide analysis indicates that the most efficient policy would utilize a mix of greenhouse gas mitigation methods including soil carbon sequestration. All of these studies show substantial potential for agriculture to play a role at low carbon prices (below \$50 per ton)⁶⁵.

Carbon Sequestration Due to Conservation Tillage in Missouri

“Conservation tillage” includes a variety of tillage and planting systems that eliminate moldboard plowing and leave crop residue on the soil surface. The MU Cooperative Extension Service recommends that “all crop producers should adopt some form of conservation tillage.”⁶⁶

⁶⁴ Follett, R.F. 2001. Soil management concepts and carbon sequestration in cropland soils. *Soil & Tillage Research* **61**: 77-92; Follett, R.F., Kimble, J.M. and Lal, R. 2001. *The Potential of U.S. Grazing Lands to Sequester Carbon and Mitigate the Greenhouse Effect*. Lewis Publishers, Boca Raton, FL; Lal, R., Kimble, J.M., Follett, R.F. and Cole, C.V. 1998. *The Potential for U.S. Cropland to Sequester Carbon and Mitigate the Greenhouse Effect*. Sleeping Bear Press, Chelsea, MI.

⁶⁵ These studies are reviewed in Antle, John M. and Bruce A. McCarl The Economics of Carbon Sequestration in Agricultural Soils, May 2001.

⁶⁶ UMC Cooperative Extension Publication G355, “No-Tillage and Conservation Tillage: Economic Considerations,” p.1

No-till, the strictest form of conservation tillage, uses no tillage of the soil except for minimal disturbance of the soil surface in the row during planting and, in some cases, during injection of fertilizers. Other forms of conservation tillage may incorporate chisel plowing or disking for soil preparation or application of fertilizer.

The NRCS definition of “conservation tillage” is that 30 percent or more of the soil surface must be covered with crop residue. In most cases, the percentage of soil cover is closer to 60 to 95 percent.

NRCS has strongly advocated conservation tillage because crop residues on the soil surface reduce erosion by water and wind. Depending on the amount of residues present, soil erosion can be reduced by up to 90 percent compared to an unprotected, intensively tilled field. Conservation tillage helps protect water quality in lakes, rivers and streams by holding soil particles and associated nutrients and pesticides on the field and sharply reducing runoff rates.

Conservation tillage also contributes to wildlife habitat and air quality. Crop residues reduce the amount of dust in the air and provide shelter and food for wildlife such as game birds and small animals. NO_x and other air emissions decrease due to reduced use and lower horsepower requirements for heavy farm equipment.

In addition to these environmental benefits, conservation tillage practices, when properly selected and managed, improve the farm’s profitability by reducing production costs and labor requirements and contributing to the soil’s long-term productivity.⁶⁷

The farmer who adopts conservation tillage does need to learn and practice new management skills since departure from familiar management practices is involved. This transition is most likely to succeed if technical assistance is available. One source of assistance is established technology transfer agencies such as the Cooperative Extension Service. Another possible source is public/private partnerships such as the Kansas Crop Residue Management Alliance, recently renamed No-Till on the Prairie.

Statistics on cropland tillage practices in Missouri during the 1990s suggest that some Missouri farmers adopted no-till and other conservation methods during the first part of the 1990s and returned to conventional tillage methods later in the decade. Although there is no survey data available on farmers’ experience with conservation tillage, it is likely that some received inadequate information or assistance in adopting the new management practices required.

MU Cooperative Extension Service has prepared generic budgets for comparing conventional tillage, no-till and other conservation tillage systems.⁶⁸ The largest cost increase is expenditures for herbicides, on which conservation tillage systems rely for weed control. The increase in herbicide costs is estimated at \$8 per acre for corn and \$3 per acre for soy.

The largest savings from conservation tillage are equipment-related. No-till systems save about \$9.50 per acre in equipment depreciation, maintenance and fuel costs. No-till systems also

⁶⁷ Beck, D.L., J.L. Miller, and M.P. Hagney, *Successful No-Till on the Central and Northern Plains*, comment that “research data can be found that support the conclusions that no-till is less profitable, more profitable, or of equal profitability to conventional systems” and discuss research assumptions that can lead to different conclusions. The bottom line is that proper selection, planning and management are key profitability of conservation tillage systems.

⁶⁸ *ibid.*

reduce capital costs for equipment, although a shift to conservation tillage is likely to require up-front investment for new planter attachments.

Conservation tillage also reduces labor requirements. The amount of the savings depends on the specific conservation tillage method adopted. Labor savings from no-till have been estimated as three to four 60-hour work weeks.⁶⁹ If the farm uses hired labor, the reduced labor requirements directly affect the bottom line. If the labor was contributed by the farmer, the reduced requirements may allow the farmer to further diversify farm operation or to pursue productive management and marketing activities.

Soil productivity is key to a farm's long-term success. A widely accepted adage says "take care of the land, and it will take care of you."⁷⁰ Conservation tillage methods improve and preserve soil productivity in many ways. Increased surface residue helps to increase and maintain organic matter in the soil, to increase moisture retention and decrease soil erosion.

Crop residues reduce water evaporation from the top few inches of the soil, making additional water available in the summer. Conservation tillage also permits channels (macropores) created by earthworms and old plant roots to remain intact, further increasing infiltration and reducing water runoff. A reduction in the frequency and weight of field traffic minimizes soil compaction and preserves soil structure. Soil particle aggregation (small soil clumps) is increased, making it easier for water to move through the soil and allowing plants to use less energy to establish roots. Reduced release of carbon gases - less tillage keeps naturally occurring carbon in the soil for use as organic matter. Intensive tillage releases soil carbon into the atmosphere as carbon dioxide where it can combine with other gases to contribute to global warming.

In addition to its many environmental and economic benefits,⁷¹ a number of studies have confirmed that conservation tillage increases sequestration of carbon in the soil and have estimated how much carbon is added using different tillage methods. Compiling and extrapolating from a number of studies that estimate carbon sequestration under different tillage methods, Conservation Technology Information Center (CTIC) has developed gross "rule of thumb" coefficients that permit an estimate of annual carbon sequestration under different tillage systems.

For the purpose of analysis, carbon tillage systems may be divided into four groups as follows. NRCS lumps no-till, mulch-till and ridge-till together as "conservation tillage," but these are distinguished here because they have different impacts on carbon sequestration.

⁶⁹ CTIC

⁷⁰ Cited in the final report of the Governor's "One Missouri" Agriculture Task Force.

⁷¹ Comprehensive discussion of the benefits of well-managed conservation tillage systems is provided in Publication MWPS-45, "Conservation Tillage Systems and Management: Crop Residue Management with No-Till, Ridge-Till, Mulch-Till" available from UMC Cooperative Extension.

Table 8: Tillage Systems and Associated Carbon Sequestration Coefficients

	No-till and strip-till	Ridge till and mulch till	Moderate till	Conventional
Degree of tillage	Minimal	Some	Moderate	Intensive
Amount of cover left on soil	Nearly all	More than 30%	15 to 30 percent	Less than 15%
(A) Annual organic matter added per acre	1,000 pounds	200 pounds	0	-400 pounds
(B) Annual carbon added per acre (equals .47 * A)	470 pounds	94 pounds	0	--188 pounds
(C) Annual CO ₂ avoided per acre (equals 44/12 * B)	1,723 pounds	345 pounds	0	-689 pounds

In reality, there is a continuum of tillage methods. At the one end of the continuum are no-till methods that avoid tilling altogether. At the other end is intensive tillage which relies on the moldboard plow to thoroughly break the soil and leaves less than 15 percent of crop residue on the surface. In between these are mulch-till, ridge-till and moderate tillage methods.

Strip-till is a variation of no-till that has been developed in the Midwest to help solve problems that farmers have experienced using no-till methods in years when the spring planting season is very wet. The technique minimizes tillage while permitting some drying of the soil.

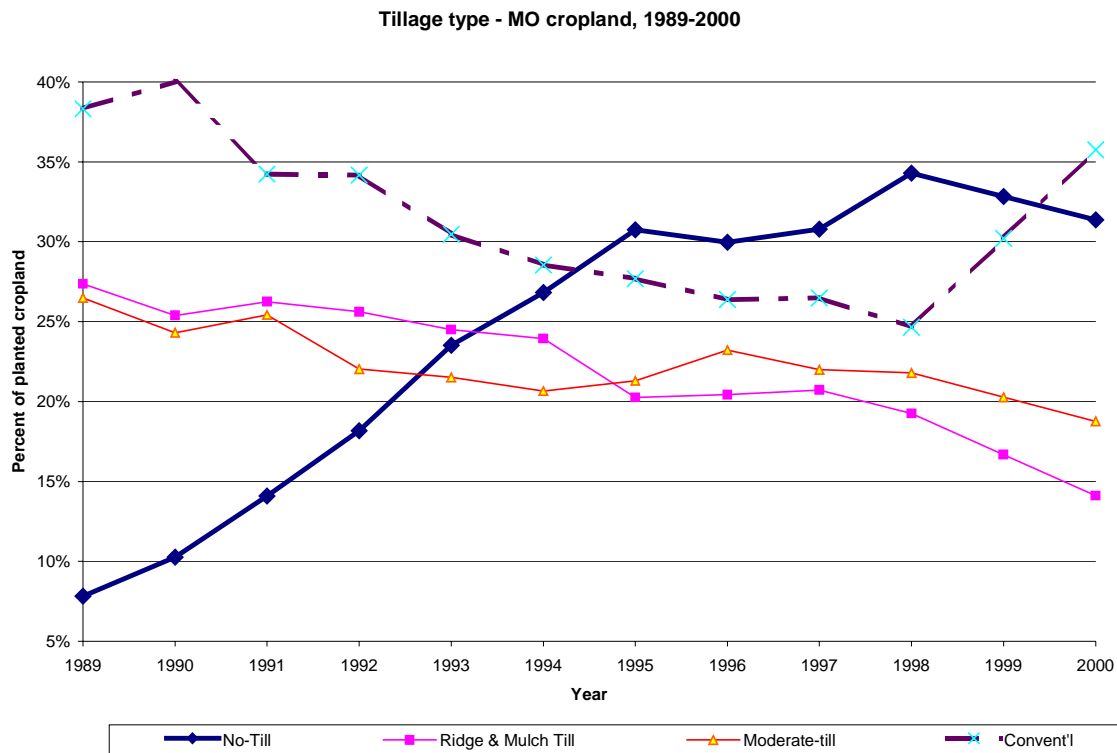
Under strip tillage, the soil is tilled in the fall instead of the spring. A third of the soil is tilled in strips 6 to 8 inches wide using a minimal-impact tillage method. The tillage strip, where next year's crop row will be planted, provides relative positions for seeds and fertilizers.

Like no-till systems, strip tillage preserves the majority of crop residue as a protective layer on the soil surface, conserves soil moisture and reduces soil erosion because only a third of the soil surface is disturbed. Because soils are usually drier in the fall than in the spring, fall strip-tillage better prepares the soil, minimizes compaction, prepares a more uniform seedbed, improves seed-to-soil contact, and dries and warms the soil ahead of spring planting rather than as a result of it.

A quarter century ago, conventional tillage was the dominant method used for crop production in Missouri. A shift toward reduced tillage began in the 1970s. By the late 1980s, less than 40 percent of total crop acreage was planted using conventional tillage. However, no-till was not yet common, used on only 8 percent of total acres. Remaining production was evenly split between moderate-till acres (26 percent) and the less aggressive conservation-till methods (27 percent).

As Chart 1 indicates, the use of no-till in Missouri increased through 1998, most dramatically in the early 1990s.⁷² As the chart indicates, no-till systems increased steadily at the expense of conventional tillage systems until about 1995 and then more slowly through 1998. However, no-till acreage decreased between 1998 and 2000.

Chart 1 - Missouri Cropland Acreage Planted Using Different Tillage Systems, 1989-2000



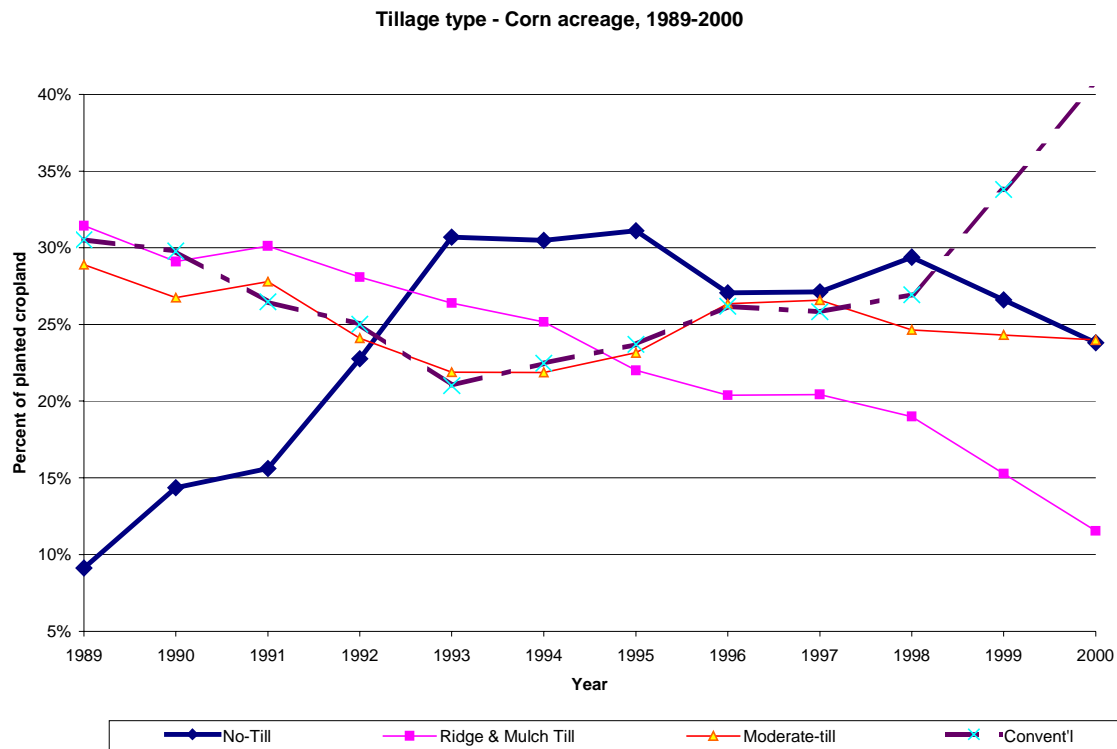
As Chart 2a indicates, no-till corn acreage in Missouri increased dramatically between 1989 and 1993, increasing from less than 10 percent of total acreage in 1989 to more than 30 percent in 1993. Acreage planted using other tillage methods decreased during this period. However, after 1993, corn acreage planted using no-till methods decreased slightly and use of other conservation tillage methods decreased significantly. After 1993, conventional tillage made a gradual comeback and then increased sharply after 1998.

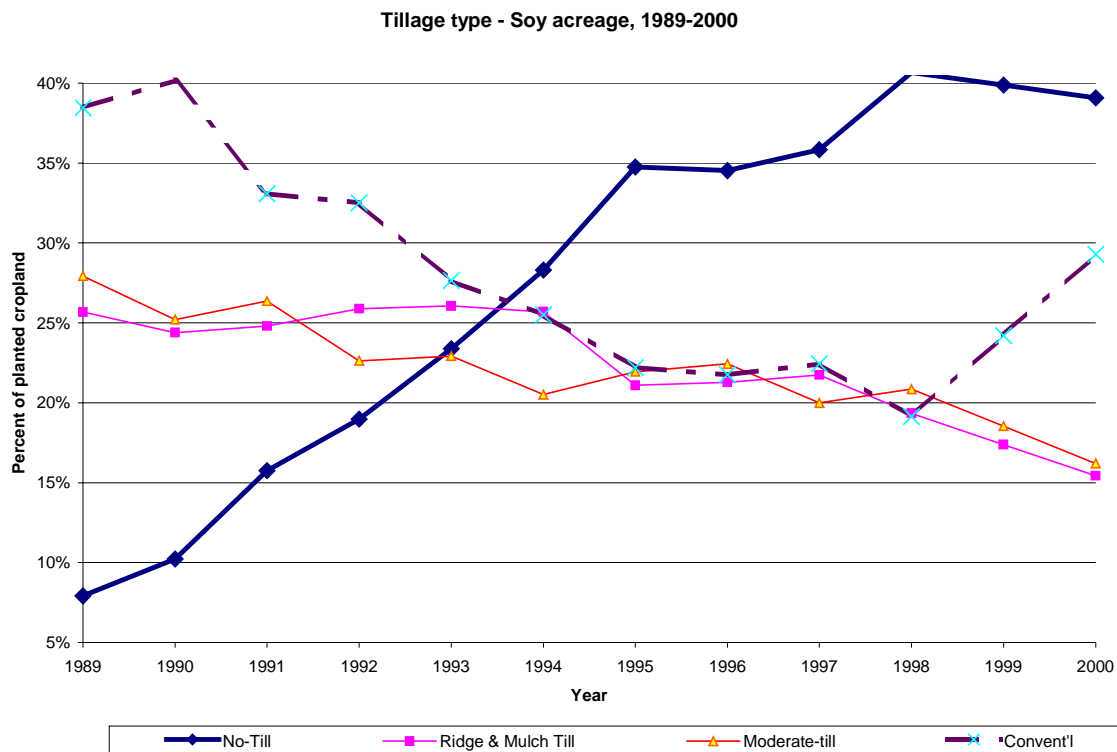
Chart 2b shows no-till soy acreage in Missouri. Between 1990 and 1998, no-till soy acreage in Missouri increased and conventionally-tilled soy acreage decreased. The rate of change was rapid between 1990-95; soy no-till acreage increased from about 10 percent to about 35 percent of all soy acreage during those years while conventionally-tilled soy acreage decreased from about 40 percent to slightly more than 20 percent. Other tillage systems also decreased slightly.

⁷² All discussion of Missouri crop acreage under various tillage systems is based on data from by NRCS National Crop Residue Management Surveys. Data points for 1999 are interpolated from data for 1998 and 2000 because NRCS switched to surveys after 1998.

After 1995, no-till soy acreage continued to increase, reaching 40.7 percent in 1998 and declining only slightly to 39.1 percent in 2000. Conventional tillage reportedly continued to decrease until 1998 but then increased 11 percent in 2000, primarily at the expense of tillage systems in the middle of the spectrum.

Chart 2a,b - Missouri Corn and Soy Acreage Planted Using Different Tillage Systems, 1989-2000



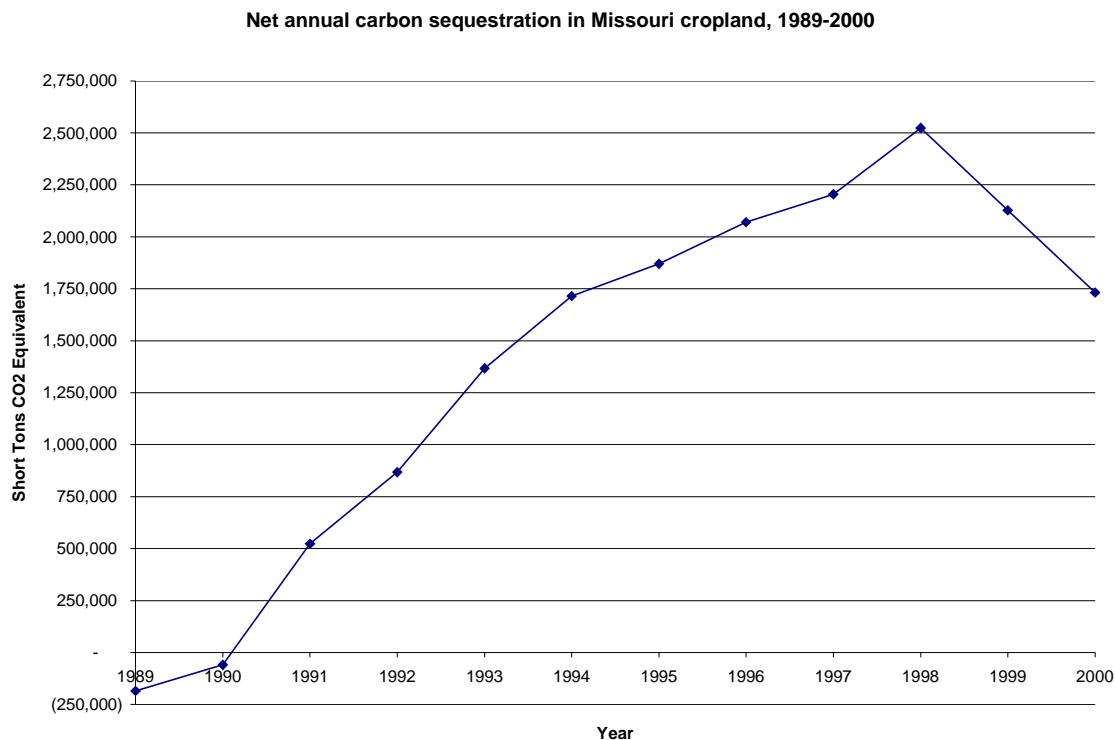


As Table 8 indicates that conventional tillage results in net carbon loss whereas conservation tillage results in net carbon sequestration. Because Missouri farmers' shifted from conventional to conservation tillage in the 1990s, agricultural soil shifted from a small (60 million tons) carbon source in 1990 to a major carbon sink, sequestering the equivalent of 2.5 million tons of CO₂ in 1998.

Table 8 displays the pattern of increase of net carbon sequestration from tillage systems during the 1990s. The estimates shown take into account both carbon sequestered by conservation tillage and carbon released by conventional tillage.

As Chart 3 indicates, between 1998 and 2000 there was a sharp decrease in net carbon sequestration from agricultural soil in Missouri, equivalent to about 800 thousand tons of CO₂. About half of this decrease was due to abandonment of conservation tillage and the other half was due to increases in conventional tillage.

Chart 3: Net Annual Carbon Sequestration from Missouri Tillage Systems, 1989-2000



There appear to be two reasons for the recent decline in conservation tillage and the increase in conventional tillage. Until the mid-1990s, there were attractive federal incentives in place to adopt conservation tillage.⁷³ After 1995, the federal incentives were reduced. For example, farmers were required to obtain approval for a conservation plan to qualify for a variety of federal agricultural payment programs. This requirement continued after 1995 but requirements for approval of the plan became less stringent.

Second, some farmers who adopted conservation tillage reportedly abandoned it when they had trouble getting into their fields following a series of wet springs that occurred in the mid- to late-1990s. Reportedly, many of these farmers blamed their troubles, rightly or wrongly, on conservation tillage. A survey of farmers who have abandoned conservation tillage might assist in researching and providing solutions that would increase farmer acceptance.⁷⁴

Commenting on a parallel farmer reaction in Indiana, John Hebblethwaite, executive director of the CTIC, suggested that those concerned with making information available on the management techniques that will allow conservation tillage to succeed “need to generate greater awareness of the techniques and technologies such as strip till available to help farmers overcome wet-weather challenges without resorting to intensive tillage.”⁷⁵

⁷³ Personal communication, Ron Miller, NCRS – Columbia, November 28, 2002.

⁷⁴ Personal communications, Raymond Massey, UMC Cooperative Extension, March 4, 2002; Dan Towery, CTIC, February 26, 2002; Bill Wiebold, UMC Cooperative Extension, February 27, 2002.

⁷⁵ CTIC, *Tillage Survey News Release*, October 29, 1996.

Agriculture and Forestry Sector Policy Options to Reduce or Sequester Greenhouse Gas Emissions in Missouri

In the agricultural sector, Missouri should take action to:

- (1) Promote electric generation and other cost-effective energy use from Missouri farm-based renewable resources.
- (2) Promote efficient energy use in farm residences and agricultural operations.
- (3) Support good agricultural management practices that reduce GHG emissions.
- (4) Expand participation in USDA conservation programs.

In the forestry sector, Missouri should take action to:

- (1) Integrate the goal of increased carbon sequestration with the goal of sustainable forestry.
- (2) Demonstrate desirable forest and natural landscape management practices on state-owned forested land.
- (3) Encourage and support sustainable forestry practices by private landowners in Missouri.

The following sections discuss specific policy options for achieving these ends. Since the policy options primarily involve promoting and supporting voluntary actions by Missouri farmers and landowners, Missouri should monitor and assess the success of expanded education, training, technical assistance, demonstration, incentives and other voluntary programs that are adopted.

Agriculture

State planning for GHG reduction policy in the agriculture sector should recognize that implementation primarily involves changing actions and behavior of private individuals.

Regulatory options to change or influence actions and behavior in these sectors exist but are more readily enacted at the federal level due to issues of interstate agricultural competition.⁷⁶ A special circumstance in Missouri is that by state law, air quality regulations more stringent than federal regulations are prohibited. Major financial incentive programs affecting these sectors also are most likely to come from federal than state action.

In light of these considerations, state planning for reducing GHG emissions in Missouri's agricultural sector should focus on providing information and technical assistance and leveraging federal programs and initiatives for which there is a demonstrable payback and existing institutional support.

Promote Generation and Other Cost-Effective Energy Use from Missouri Farm-Based Renewable Resources Including Biomass and Wind Resources

The rationale for renewable energy use and generation as a strategy to reduce GHG emissions is developed at length in the technical sections of this chapter and in the Generation chapter. In

⁷⁶ See State and Territorial Air Pollution Program Administrators (STAPPA) and Association of Local Air Pollution Control Officials (ALAPCO), *Reducing Greenhouse Gases and Air Pollution: A Menu of Harmonized Options*, Final Report, Washington, D.C., 1999, Chapter VIII.

general, renewable energy use and generation reduce GHG emissions and also provide numerous other public benefits. Developing on-farm renewable energy resources has the potential to boost farmer income, create jobs in rural communities, diversify our energy resources and lessen our dependence on imported fossil fuels.

The state should promote both on-farm generation for self-use and the development of utility-scale renewable generation. Utility-scale generation can provide new markets and sources of income for Missouri farmers.

In addition, Missouri should promote cost-effective on-farm use of biomass as a source of heat. Promising opportunities include direct use of livestock or crop wastes for heat; methane capture from livestock operations, discussed elsewhere; and combined heat and power (CHP) applications in situations in which the need for heat is primary and there is a secondary need for electricity that could be generated from waste heat. On-farm CHP is currently being demonstrated by projects in the United States and Europe.

Some provisions in farm bills currently being considered by the U.S. Congress provide for a substantial increase in incentives and programs to promote renewable generation on farms and from agricultural resources. The Missouri Department of Conservation and other state agencies work closely with NRCS and FSA to develop programs and practices that make new federal funding available to landowners. If the federal government funds these or similar proposals in the future, Missouri should develop a coordinated interagency plan to help Missouri farmers take advantage of the new programs and incentives.

Coordinate Efforts to Provide Accurate and Timely Information, Research and Technical Assistance to Managers of Agricultural Operations Interested in On-Farm Renewable Generation or Renewable Energy Use

Several state agencies including the Department of Agriculture; Department of Natural Resources; Department of Conservation; University of Missouri College of Agriculture, Food and Natural Resources; and MU Cooperative Extension Service provide publications and technical assistance to farmers and agricultural operators in Missouri. These agencies should coordinate efforts to provide accurate and timely management and technical information in response to queries such as the following:

- Queries from managers of CAFOs and other large livestock operations in Missouri who want to determine or exploit the potential for generating electricity from methane created from livestock manure management.
- Queries from farmers interested in the potential for on-site generation from wind or solar sources.
- Queries from farmers interested in efficient and sustainable use of wood, waste or other biomass as a fuel source.
- Queries from farmers interested in on-farm use or potential markets for corn ethanol and soy diesel. The Transportation chapter includes additional discussion of policy options to promote ethanol and soy-diesel markets and infrastructure.

These state agencies should also assist farmers in identifying and obtaining federal assistance for on-farm renewable energy use or renewable generation.

Promote Partnerships Between State Agencies, Legislators and Agricultural Organizations and Interests to Develop and Use Farm-Based Renewable Energy

Partnerships including legislators, the departments of Agriculture, Natural Resources and Economic Development, the University of Missouri, agricultural organizations such as the Missouri Farm Bureau and the Missouri Farmers' Union, and rural electric cooperatives should come together to promote the development and use of biomass, wind and solar energy.

Missouri should help form partnerships between farmers and those industries that can use biomass to fuel boilers.

Missouri should include biomass-based fuels in its plan to reduce the loss of nutrients to waterways to reduce nutrient impacts in Missouri and in the Gulf of Mexico. For example, poultry litter in southwest Missouri could be burned as an energy source and the resulting ash can be shipped out of problem watersheds and marketed as a phosphorus- and potassium-rich fertilizer. The end result would be an additional income stream to Missouri poultry producers, a reduction in water pollution and displacement of fossil fuels.

Obtain an Accurate and Detailed Map of Missouri Wind Energy Resources with the Goal of Identifying and Promoting Opportunities for Generation from Wind Farms Located in the State's Rural Areas

As described in the technical section, there is reason to believe that an accurate and detailed map of Missouri's wind resources would indicate a number of areas in which wind farms could be profitably developed.

Wind farming would provide a new source of income to Missouri farmers and farm communities as well as reducing CO₂ emissions by displacing generation that would otherwise occur from non-renewable sources. The experience of other states where wind farms have already been developed on leased agricultural land indicates that farmers can reap substantial economic benefit from developing these renewable resources. By leasing land to a wind developer, a farmer can earn on average of \$2,000-3,000 a year per wind turbine, with little land being taken out of production. Rural communities benefit from increased tax revenues and the creation of new construction and maintenance jobs.

Promote the Development of a Market for Biomass Energy Resources Grown on Missouri Farms by Encouraging or Requiring Missouri Utilities to Develop Renewable Generation in the State

The Generation chapter discusses a number of policy options for encouraging or requiring Missouri utilities to develop renewable generation. One regulatory option is to require utility investment in renewable generation.

Missouri should support, and as appropriate, form partnerships with Missouri farmers or utilities to develop a utility market for farm-based biomass. Missouri should actively encourage utility-farm communications and partnerships to develop viable markets and supplies for biomass co-firing in utility coal-fired or gas-fired plants. In addition to biomass crops, wastes from agriculture and timber practices — like wood chips, animal agriculture residues and the non-food parts of crops — could be used for co-firing. This effort should begin with existing biomass resources but might lead to the development of markets for biomass crops that could be grown

on marginal lands not suitable for conventional crops. Removal of biomass resources should be done in a manner that leaves sufficient residues to assure soil health and avoid excessive erosion.

A project sponsored by the Missouri Department of Natural Resources and the U.S. DOE Office of Power Technologies, and administered by U.S. DOE's Southeastern Regional Biomass Energy Program (SERBEP), will assist rural electric cooperatives in identifying opportunities to use locally available biomass fuels for electric generation, including grasses, trees and sawdust. The state should closely monitor the progress of this project and facilitate efforts to incorporate biomass into the utilities' generation mix.

Establish a Legal and Regulatory Framework that Encourages On-Site Generation from Renewable Sources on Missouri's Farms

As elaborated in the Generation chapter, the measures that the state should develop include a provision for net metering of on-farm generation and consistent, non-discriminatory interconnection standards.

Support Expansion of Several Titles in Federal Farm Programs to Encourage the Development of Farm-Based Renewable Generation

Missouri could advocate that the federal Conservation Reserve Program (CRP) be expanded to accommodate and encourage the development of renewable generation resources. The CRP program is the largest of the USDA conservation programs, with an enrollment cap of 36.4 million acres, equivalent in size to the state of Iowa. 1.6 million acres in Missouri are currently enrolled in the program.

Missouri could advocate that USDA allow farmers to:

- Site wind turbines on CRP lands where ecologically and economically appropriate.
- Grow and harvest biomass crops on CRP land with an appropriate reduction in rental payments and continued restriction on haying for livestock. Allowable energy crops should be restricted to perennial vegetation.

The mission of the CRP program is to preserve land vital for soil conservation, water quality protection, and wildlife habitat. If renewable energy production is added to CRP's mission there must be restrictions to assure that the original goals of the program are not diminished.

Therefore, in order to be approved, wind energy and biomass development projects on CRP lands should be compatible or enhance the soil conservation, water quality and wildlife habitat goals of the CRP program.

In addition to the CRP program, Missouri could advocate that the mission and funding of several other federally funded programs be extended as follows:

- That the Rural Business-Cooperative Service (RBS) continue to expand its mission to include providing grants and loan guarantees to establish cooperatives or expand existing cooperatives to undertake wind, biopower, biofuel and bioproduct development.
- That the Cooperative Extension Service continue to expand its mission to provide information and technical assistance to farmers and farmer-owned co-ops for the development and marketing of renewable energy resources, including biomass, wind, solar, low-head hydropower and geothermal.

- That the interagency Biomass Research and Development initiative be fully funded at its authorized level of \$49 million a year and extended past 2005. This initiative would substantially strengthen information about agricultural sequestration of carbon.
- That funding be increased for agricultural energy related projects in the State Energy Program (SEP) administered by the U.S. DOE. A number of states have used grants from the SEP to increase energy efficiency in agriculture.

Promote Efficient Energy Use in Farm Residences and Agricultural Operations

As described in the technical section of this chapter, significant energy savings are possible in Missouri farm buildings and operations. Many of the policy options described in the Buildings chapter could apply equally to farm buildings.

Farm bill legislation considered by Congress includes a major title that provides new funding for technical assistance and incentive programs to promote energy efficiency on the nation's farms. An increase in federal funding would open new opportunities for voluntary programs to promote agricultural energy efficiency in Missouri. For example:

- Farm bill proposals include a provision funding "whole farm energy audits." Missouri could undertake a coordinated effort to encourage and support the participation of Missouri farmers in such audits.
- Missouri could provide grants for on-farm projects demonstrating farming methods or systems that increase energy efficiency and achieve other environmental and economic benefits. This could be accomplished by expanding the Missouri Sustainable Agriculture Grant Program administered by the Missouri Department of Agriculture Plant Industries Division. In addition, the state could help Missouri farmers take advantage of Sustainable Agriculture and Education Program demonstration grant programs.

Support Good Agricultural Management Practices that Reduce GHG Emissions

Examples of good crop management practices that increase carbon sequestration or reduce GHG emissions include conservation tillage, improved cropping systems and erosion control and precision farming techniques including proper application of nitrogenous fertilizer.

Examples of good livestock management practices that reduce GHG emissions are improved livestock feed and manure management practices. There also are opportunities to displace fossil fuels with methane from manure management systems.

Examples of agroforestry practices which, properly managed, increase carbon sequestration include windbreaks, riparian forest buffers, silvopasture, planting of short-rotation woody crops, and any tree planting and long-term forest management that increases forest health and vigor.

Further discussion of the GHG and other benefits of these management options is included in the technical section of this chapter.

Support should be accomplished through research, information and technical assistance in coordination with USDA. In addition, state agencies should identify federal sources of support or incentives for these management practices and help Missouri farmers to obtain them.

In addition, the state could study the possibility of providing or facilitating the availability of risk management insurance targeted at reducing the economic risk of otherwise desirable management practices. An example described in the technical section of this chapter is reliance on staged application of fertilizer rather than one-time application at planting time.

Expand Participation in Conservation and Other Federal Programs that Promote Practices that Contribute to GHG Reduction and Carbon Sequestration in Missouri's Agricultural Sector

The long-term conversion of grassland and forestland to cropland (and grazing lands) has resulted in historic losses of soil carbon worldwide but there is a major potential for increasing soil carbon through restoration of degraded soils and widespread adoption of soil conservation practices.

Because carbon sequestration is compatible with other environmental goals important to agriculture, USDA's conservation programs and many conservation practices available to and being used by landowners represent a multifaceted opportunity in light of climate change. Principal conservation strategies that sequester carbon include converting marginal lands to compatible land uses, restoring degraded soils, and adopting best management practices. Soil conservation practices not only reduce soil erosion but also increase the organic matter content of soils. Adoption of appropriate conservation strategies leads to carbon sequestration in the soil, improved soil quality, increased productivity, more sustainable land use and an enhancement of overall environmental quality through improved wildlife habitat, higher water quality and erosion reduction. Removing agriculturally marginal land from production and adopting an ecologically compatible land use, such as wildlife habitat, can lead to increases in total biomass production and an increase in carbon content in the soil

Missouri farmers already participate in a number of federal conservation programs. Missouri should continue to collaborate with the federal government in making federal conservation programs available in Missouri, including programs to conserve farmland and forestland, and encourage and support the participation of farmers and other Missouri landowners in these programs. Potentially, it could also include state support for farmer participation in a federal carbon credit program.

Participate in USDA's Farmland Protection Program

USDA's Farmland Protection Program (FPP) helps landowners retain farmland that is threatened by urban sprawl and might otherwise be converted to different uses. As discussed in the technical section, conversion of farmland at urban margins to other uses generally results in an increase in CO₂ emissions and a reduction in soil carbon sequestration. In addition, many other social and public interest purposes are served by farmland protection.

The FPP preserves farmland by providing federal money to help state agencies or not-for-profit organizations create "conservation easements" under which the landowner retains general ownership and control of the property.

Funds are awarded through a once-a-year competitive process in response to proposals by state agencies or not-for-profit organizations such as land trusts. Since no state agency or not-for-profit organization in Missouri has ever submitted a proposal for funding, none of this funding has ever been awarded to Missouri.

The FPP program will likely be reauthorized by Congress and expanded with increased funding. Congress may also extend the program to include farmland with historic and archaeological resources, which would provide a new mechanism to meet historic preservation goals in Missouri.

If the program is reauthorized and expanded, Missouri agencies should identify opportunities to participate and submit suitable proposals acting alone or in partnership with a Missouri-based land trust.

Actively Support Other Federal Conservation Programs that Protect Ecosystems and Increase Sequestration on Rural Crop and Forestlands

USDA programs such as the CRP, the Wetland Reserve Program, the Wildlife Habitat Incentives Program, the Stewardship Incentive Program, Forestry Incentives Program and the Secretary's conservation buffer strip initiative all help increase soil organic carbon. Farm bills considered by Congress would increase federal funding for these programs.

USDA's Environmental Quality Incentive Program (EQIP) offers technical assistance and cost-share payments to landowners for implementing certain forest and wildlife habitat management practices. The two most common programs are tree planting and improvement to an existing stand of trees. EQIP is administered by the NRCS.

The USDA/U.S. Forest Service Forest Legacy Program (FLP), a federal program in partnership with states, provides funds to help states protect environmentally sensitive forest lands and address issues such as forest fragmentation and conversion. Designed to encourage the protection of privately owned forest lands, FLP is an entirely voluntary program that focuses on the acquisition of partial interest in privately owned forest lands. FLP helps the states develop and carry out their forest conservation plans by supporting the acquisition of conservation easements, legally binding agreements transferring a negotiated set of property rights from one party to another, without removing the property from private ownership. Most FLP conservation easements restrict development, require sustainable forestry practices and protect other values.

Various farm bill proposals would also add new federal incentive and information programs for owners of forestlands. These proposals would expand federal and state capacity for information and technical assistance to landowners and enable private non-profit organizations to help forest owners develop sustainable forestry management practices. These proposals are intended in part to slow the processes of forest fragmentation and urban intrusion into forested lands.

If a Carbon Credit Program is Developed at the National or International Level, Work to Assure that Missouri Farmers Obtain Credits for Agricultural Resource Management Practices that Reduce or Sequester GHG Emissions

Demand for "carbon sequestering" through agriculture could be created by any of four sources: an international climate change treaty that requires countries to reduce their net GHG emissions; a farm bill from Congress that creates incentives for farmers to trap carbon; a move by the federal administration to limit U.S. carbon dioxide emissions; or a voluntary agreement that allows carbon dioxide emitters to buy offsetting credits from farmers.

One of the foremost options being considered for reducing U.S. GHG emissions amid increasing concern about global warming is a plan to pay farmers for agricultural practices that reduce

carbon in the atmosphere. Farmers would be compensated for implementing or continuing practices that reduce carbon emissions from the soils. The compensation could potentially come from the government or from companies that are interested in “trading” carbon credits.

Farmers have a number of opportunities to reduce or sequester CO₂, methane and nitrous oxide emissions. Tree planting, conservation tillage, soil improvement practices, wind and biomass-based renewable generation, retirement of marginal cropland and good management of energy, livestock feed, livestock wastes and nitrogenous fertilizer reduce or sequester GHG emissions and should be eligible for credit.

It should be recognized that changes in soil carbon stocks are difficult to verify due to temporal and spatial heterogeneity. The most direct means of determining soil carbon sequestration is to measure, over time, sequential changes in soil carbon. As discussed in the technical section of this chapter, such measurements are complicated by the slow rate of change and field-scale variability and there is widespread agreement by researchers that additional studies are required to develop and standardize a methodology for measurement and verification.

Missouri should monitor proposals that would create a system of “carbon credits.” If a system of carbon credits is established, the state should provide technical assistance to Missouri farmers to obtain and sell credits and should work to assure that measurement and verification requirements for farm-based credits are not unduly intrusive.

Forestry

With respect to GHG emissions, the major role of Missouri’s forest sector is to serve as a carbon sink, offsetting millions of tons of carbon emissions from other sectors. In 1990, Missouri forests sequestered an estimated 27 million short tons of CO₂ emissions that would otherwise have entered the earth’s atmosphere. Through 2015, the projected level of carbon sequestration from Missouri forests is projected to decrease slightly to 23 million tons per year.⁷⁷

This chapter discusses a number of methods for assuring that trees will continue as a major carbon reservoir. These include agroforestry, urban tree planting and the establishment of forest reserves and parks. However, the principal focus of this chapter is on promoting sustainable management of forestland. Sustainable forestry achieves a number of benefits including carbon sequestration. In addition to its immediate impact on the amount of carbon locked into trees, sustainable forestry assures that this carbon reservoir will persist for decades to come and helps to prevent conversion of forest land to other uses by increasing its value as forest land.

⁷⁷ Greenhouse Gas Emission Trends and Projections for Missouri, 1990-2015, Chapter 6. These results indicate that total carbon sequestered in woody biomass increases each year. The projected decrease is in the *rate* at which new carbon is sequestered. The Trends report includes extensive discussion of methodological issues in estimating the rate of sequestration.

Integrate the Goals of Increased Carbon Sequestration in Missouri's Forestry Sector and Sustainable Forestry

Sustainable forestry is a modern and evolving concept. One succinct definition is “the practice of managing dynamic forest ecosystems to provide ecological, economic, social and cultural benefits for present and future generations.”⁷⁸

As is documented in the technical section of this chapter, sustainable forestry provides many benefits to Missourians including its contribution to the long-term sequestration of carbon in trees and forest soils.

Recent statements indicate Missouri's commitment to the goal and principles of sustainable forestry. For example, the Missouri Department of Conservation defines “the aim of forest management” as “a healthy, sustainable forest that accommodates any number of uses by the landowner.”⁷⁹ A joint resolution by the Missouri legislature commended the creation and implementation of Missouri's Sustainable Forestry Initiative Program as a means to achieve “responsible stewardship of Missouri's forests, water resources, and wildlife” in accordance with principles of sustainable forestry.⁸⁰

An advisory committee established by former Governor Mel Carnahan to study issues related to chip mills summarized the role of sustainable forestry as follows: “Sustainability of all forest resources is critical and can be influenced for better or worse by the kinds of practices conducted on forest lands in the state. This inherently involves sustaining the unique geological underpinning and rich heritage of biodiversity of Missouri forests. A sustainable environment encompasses both the living and non-living elements of forest ecosystems. The living components include diverse and viable wildlife populations, trees of mixed species and ages, and contiguous blocks of forested landscapes. Sustaining such an environment also requires minimizing soil loss, ensuring the integrity of watersheds, and safeguarding clear streams and springs.”⁸¹

Create Opportunities to Demonstrate Desirable Forest and Natural Landscape Management Practices on State-Owned Forested Land

On an overall basis, slightly less than one-third of Missouri -- approximately 14 million acres -- is covered by forestland. About 15% of this area is public land, most of which is administered by either the U.S. Forest Service (USFS) or the Missouri Department of Conservation (MDC). State-owned forested land consists primarily of conservation areas operated by MDC and state parks operated by the Missouri Department of Natural Resources.

The MDC practices sustainable forestry, including selective harvesting of trees, on a half million acres of land in accordance with the Sustainable Forest Initiative (SFI) Standard.

⁷⁸ Bruce Palmer, *Sustaining Missouri's Forests*, Missouri Conservationist Sept 2000 p 18.

⁷⁹ Missouri Department of Conservation, *Forest Management for Landowners*, Jefferson City, 2000

⁸⁰ Senate Joint Resolution 31, concurred in by Missouri House of Representatives, May 2000.

⁸¹ Final Report, Governor's Advisory Committee on Chip Mills, Jefferson City, 2000. The membership of the advisory committee included representatives from industry, state and private sector groups.

The Department of Natural Resources' Division of State Parks manages state park land with a commitment to preservation of biodiversity and natural landscapes. Within the Division of State Parks' Natural Resources Management Plan, which is focused on restoring ecosystems, the practice is to let timber lie so that soil carbon is restored. Controlled burning, discussed in the technical section of this chapter, is also used as a forest management technique.

Both the department and MDC already use some forested land to demonstrate desirable forest and natural landscape management practices to landowners and the general public. The agencies should identify and pursue additional demonstration opportunities through means such as publications, on-site signs and displays and on-site demonstration tours. This effort could be conducted by the individual agencies or could be part of a coordinated effort such as might be organized by a Missouri Forest Resource Council, described below.

Encourage and Support Sustainable Forestry Practices by Private Landowners in Missouri

Almost 96 percent of the forestland in Missouri, or about 13.4 million acres, is classified as timberland. The majority of these lands – approximately 83 percent or 11.1 million acres -- is controlled by non-industrial private forestland (NIPF) owners. The Missouri Forest Products Association's estimate that "less than half a million of these acres are being managed as a sustainable crop," probably understates the extent of sustainable forestry practices in Missouri. For example, Pioneer Forest, 150 thousand acres, is sustainably managed but not in the Tree Farm program. However, reliable statistics are not currently available on how many of these acres are now managed sustainably.⁸²

Nearly all of Missouri's wildlife and the bulk of Missouri's forest products are found on private lands. The commitment of private landowners to managing their forestlands sustainably is key to achieving the many private and public benefits of sustainable forestry management in Missouri, including benefits related to carbon sequestration.

Most NIPF land is in larger tracts. Nearly 77 percent of total NIPF acreage resides in tracts of 50 acres or more and about 57 percent resides in tracts of 100 acres or more. On the other hand, the great majority of NIPF landowners have their land in small tracts. In Missouri, nearly half of NIPF owners have tracts of less than 10 acres, and 79 percent own tracts of less than 50 acres in size. According to the most recent available USDA/USFS forest inventory statistics, the total number of NIPF landowners in Missouri increased dramatically in recent decades, from about 81,000 owners in 1978 to 307,000 in 1994.

In the absence of statistical data, it is difficult to assess trends in Missouri toward fragmentation of forestland and the conversion of forestland to other uses. It appears that the rapid fragmentation of forestland in Missouri that occurred in earlier decades has slowed recently. However, the conversion of forestland to urban uses has continued to occur on the fringes of Missouri's metropolitan areas and in rapid growth areas such as the Branson area of southern

⁸² Missouri Forest Product Association web site <http://www.moforest.org/treefarmssystem.htm#Who>

Missouri. USDA/USFS is currently developing statistics that will permit a more authoritative assessment.⁸³

As discussed in the technical section of this chapter, improvements in the management of forested land as a sustainable resource are likely to result in greater carbon sequestration, due to improvements in tree selection, improved harvest techniques and the reduction of wood waste that might otherwise release carbon to the atmosphere. Improved management also increases the value of forestland and reduces the risk of conversion to other uses that would result in the release of soil carbon and the loss of carbon sinks.

Encourage Widespread Participation in the Missouri Tree Farm Program and Missouri Sustainable Forestry Initiative

The Missouri Tree Farm Program, affiliated with the American Tree Farm System, is a forest industry-sponsored program that reaches out to NIPF landowners in Missouri, assists them in managing their forest land sustainably and offers a certification program that potentially enhances the market value of the tree farmer's product. The Missouri Tree Farm program began in 1949 and now enrolls more than a thousand certified tree farms.

The Missouri Tree Farm Program is sponsored by the Missouri Forest Products Association and supported by MDC. Members of the program set the direction and policy of the Missouri Tree Farm Program through the Missouri State Tree Farm Committee. Nationally, the American Tree Farm System is sponsored by the nation's forest industries through the American Forest Foundation and endorsed by a number of public and private organizations.

To join and gain certification, the landowner is required to meet certain standards and guidelines including development of a management plan based on strict environmental standards and guidelines and inspection by volunteer foresters who donate their expertise to the program. Volunteer foresters reinspect tree farms every five years to verify adherence to Tree Farm's sustainable forest management standards and guidelines. In Missouri, all MDC foresters and many private consulting foresters are available as volunteer inspectors.

Missouri's SFI, sponsored by the Missouri Forest Products Association, is affiliated with the national SFI program of the American Forest & Paper Association (AFPA). The initiative is a comprehensive system of principles, objectives and performance measures that integrate the long-term, sustained growing and harvesting of trees with the protection of the environment in which they grow. The heart of the program is the SFI Standard, which defines the following twelve measurable objectives as annual action items:

1. Broadening the practice of sustainable forestry.
2. Ensuring prompt reforestation.
3. Protecting water quality.
4. Enhancing wildlife habitat.
5. Minimizing the visual impact of harvesting.
6. Protecting special sites.

⁸³ The adverse social, economic and ecological consequences of forest fragmentation have been widely discussed. A good source is the *Proceedings of Fragmentation 2000: A Conference on Sustaining Private Forests in the 21st Century*. The conference took place in September 2000.

7. Contributing to biodiversity.
8. Continuing improvements in wood utilization.
9. Continuing the prudent use of forest chemicals to help ensure forest health.
10. Fostering the practice of sustainable forestry on all forestlands.
11. Publicly reporting on their progress.
12. Providing opportunities for public outreach.

Through an SFI State Implementation Committee (SIC), Missouri could develop a private-public partnership to promote and inform stakeholders about the SFI. State implementation committees based on partnerships between the forestry industry, state government and citizen groups have been active in a number of states.

For example, Michigan's implementation committee, created in 1995, is made up of AFPA member companies, independent loggers, forestry associations, forestry consultants, academicians, conservation organizations and public agencies. The SIC has a budget to administer SFI programs, and to conduct the necessary training. Member companies contributing funds based on an assessment of their annual wood consumption generate this budget. In Michigan, the Michigan Forest Resource Alliance is the umbrella organization that actually administers the SFI funds.

Examples of SFI programs initiated by SICs in other states include a Master Logger program conducted by the Tennessee SIC, county field days and landowner conferences conducted by the Kentucky SIC and landowner clinics, educator workshops and ecosystem workshops conducted by the Arkansas SIC.

Establish a Missouri Forest Resource Council and Encourage the Voluntary Association of Landowners to Promote Sustainable Forest Management in Missouri

The Governor's Advisory Committee on Chip Mills recommended establishment of a Forest Resource Council to serve at least the following roles:

1. Foster collaboration and provide an ongoing public forum among landowners, loggers, wood-based industries, environmental interests, the tourism industry, public agencies and others with a vital vested interest in the well-being of Missouri's forest resource.
2. Advise the governor and state, county and local governments on sustainable forest resource policies and practices.
3. Coordinate priority forestry research efforts in the state and develop and implement initiatives in sustainable forest management.

One function of the resource council could be to further a public-private partnership to promote widespread participation in the Missouri Tree Farm System, Missouri Sustainable Forestry Initiative and other voluntary efforts to inform and promote sustainable forest management practices among Missouri landowners.

Coordinate Information and Technical Assistance Efforts with the Goal of Providing Every Forest Landowner with a Working Knowledge of Sustainable Forest Management Practices

Training and professional management are critical to the long-term sustainability of Missouri forests. Several public sector organizations now provide information, training and technical assistance on forest management to landowners in Missouri. The state should assess opportunities to further coordinate these efforts and seek out opportunities for partnerships with private sector organizations in this effort.

- The MDC offers a wide range of landowner assistance programs. Some programs are cooperative efforts with the federal government while others are unique to MDC. Free technical advice and services provided to landowners by MDC foresters include preparation of management plans and on-the-ground advice and assistance on topics such as tree planting, species selection, woodland management, timber stand improvement, wildfire protection, insect and disease detection, woodland wildlife management and commercial aspects of timberland management. In addition, MDC foresters give advice on available federal and state financial assistance for conservation-oriented forestry and land management practices.
- Other state agencies that provide information, training and technical assistance on forest management include the Missouri Department of Agriculture, Department of Natural Resources, the soil conservation districts, MU Cooperative Extension Service and University of Missouri School of Natural Resources. The University of Missouri and MDC jointly publish the *Green Horizons* newsletter that provides landowners with information about forestry-related associations and programs in the state.
- Several USDA agencies provide information, training and technical assistance on forest management including USDA Extension, USDA/USFS and the USDA Natural Resources Conservation Service (USDA/NRCS).
- In Missouri, experts from these agencies are available to help landowners make informed decisions about the stewardship of their property. These professionals -- including foresters, wildlife and fisheries biologists, soil scientists and extension specialists, all of whom provide services free of charge -- can show landowners how to manage property in a sustainable manner and inform them about incentive programs to help offset expenses of management practices.
- Private sector organizations that provide landowner information, training and technical assistance include the Missouri Consulting Forester Association, the Missouri Forest Products Association, the Missouri State Tree Farm Committee, the Missouri Christmas Tree Producers Association, the Missouri Nut Growers Association and the Missouri Walnut Council.

Development of a Missouri Forest Resource Council (MFRC) would offer an opportunity for further coordination of information, training and technical assistance efforts. The MFRC could help develop and evaluate effective forest landowner information and training programs, recommend development of programs and legislation that assist owners in learning about the care of their forest resources, and develop and evaluate initiatives directed to the great majority

of forest landowners who hold small tracts of land for purposes other than commercial tree farming.

Encourage Private Landowner Participation in Federal and State Incentive Programs that Promote Tree Planting and Sustainable Forestland Management

Several USDA programs provide financial incentives for conservation practices that include tree-planting and sustainable forestland management. These programs include:

- The USDA Farm Service Agency's Conservation Reserve Program, through which landowners can receive cost-share benefits and 10-15 year annual rental payments for establishing conservation practices such as tree planting and wildlife cover.
- Several programs administered by the USDA/NRCS that offer cost-share benefits to landowners who plant trees, perform timber stand improvements, restore and protect wetlands or improve wildlife habitat.

If there is an increase in federal funding for USDA or other federal programs that provide financial incentives for conservation practices, the state should expand its efforts to enroll landowners in these federal programs.

Missouri operates two state-funded programs that offer incentives to implement sustainable forestry and land management practices, as follows:

- The MDC's Forest Cropland Program offers property tax reductions to landowners in return for agreeing to follow an approved forestland management plan for 25 years.
- Through the Missouri Soil and Water Districts Commission's statewide resource conservation programs, landowners can receive financial benefits for establishing or protecting woodlands as part of authorized erosion control and conservation projects. These programs are funded by specific taxes - the 1/8 percent Conservation Tax and the 1/10 percent Parks and Soils Tax.

To the extent permitted by current funding sources, these Missouri incentive programs could be expanded and aggressively marketed to enroll landowners in the programs. In addition, the state could consider use of the revenues derived from the soil conservation portion of the Missouri Parks and Soils Sales Tax to sustain soil productivity for sustainable forest management and forest resources in Missouri within the guidelines of current legislation.⁸⁴

The MDC's George O. White State Forest Nursery grows and sells seedlings at cost to Missouri landowners as well as public agencies and communities. The seedling program is well-publicized among rural landowners and during the past four years, it has expanded from approximately 3 million to nearly 6 million seedlings supplied annually. The largest variable affecting demand for the seedlings is participation by landowners in USDA's cost-share programs.

If there is a major increase in landowner participation in cost-share programs that compensate landowners for the cost of planting trees, the demand for seedlings may outgrow the supply available from the George O. White State Forest Nursery. The state should monitor landowner

⁸⁴ These actions were unanimously recommended by the Governor's Advisory Committee on Chip Mills.

demand for seedlings and develop plans for expanding seedling production if demand exceeds supply.

Explore Opportunities to Support the Establishment of “Green Marketing” for Wood Products Cut from Sustainably Managed Forests

A recent Purdue University survey found that 68 percent of those polled would be willing to pay more for furniture whose materials originated from a sustainably managed forest.⁸⁵

Several organizations and companies provide third-party certification intended to permit landowners who follow principles of sustainable forest management to take advantage of this potential “green market” for their products.

There are several obstacles to green marketing of wood products in Missouri. First, establishment of a single certification standard is probably a requirement for establishing widespread consumer knowledge and acceptance. As with green marketing of electricity, Missouri could participate in a voluntary effort to define a “green” standard for wood products and provide information about this standard to consumers.

Second, the cost of initial certification and annual audits is high. Depending on the certification program that is established, Missouri could help small landowners allay the cost of certification by promoting certification of foresters. Many small landowners use a forester to assist with managing their forestland. By working with a certified forester, the landowner might gain endorsement by virtue of the forester’s certification. Several landowners in an area working collectively with a certified forester might further reduce the cost of endorsement. This would require changes in current national certification programs.

An additional obstacle is the cost of maintaining separate inventories of certified products and assuring that a certified product is traceable as it moves from a forest to the ultimate end user.

Expand Tree Planting and Other Land Cover on Missouri’s Non-Forest Land

Identify and Take Advantage of Opportunities to Expand the Planting of Trees and Native Land Cover Species on Non-Forested Land Owned by the State

In addition to forested land, there is a large, although unknown, amount of state-owned land adjoining state facilities or state highways. Many such areas could be planted with trees or native land cover species using state funds.

State agencies should undertake a coordinated effort to inventory and assess opportunities to plant trees or ground cover in such areas and give high priority to such investments. The assessment should take into account that an increase of plant materials in these areas may serve multiple purposes such as reducing noise, improving aesthetic value, filtering dust and pollution from the air, reducing runoff, providing shade and windbreaks and otherwise contributing to energy conservation.

⁸⁵ Palmer, op cit.

In coordination with this planting program, the state could develop materials for use by participating agencies to explain to the general public the benefits of tree and land cover planting.

Expand Current Programs to Promote Tree Planting by Urban Residents and Communities

At present, MDC operates two closely integrated urban-oriented forestry programs that offer information and technical assistance to residents and communities. Urban foresters located in St. Louis, Kansas City, Springfield, Columbia, Joplin, St. Charles, Eureka and Cape Girardeau offer information and technical advice to the general public. The Community Forestry program emphasizes planning assistance to Missouri towns for planting and managing trees in public areas. Community forestry plans, prepared in response to community requests, may include on-site advice with sketches or detailed written plans with scaled drawings.

MDC's Tree Resource Improvement and Maintenance II (TRIM II), administered in cooperation with the Missouri Community Forestry Council, provides financial assistance for the management, improvement or conservation of the urban and community forest on publicly owned land in Missouri. TRIM II replaced the combined elements from MDC's previous tree planing cost share program, Branch Out Missouri, and tree maintenance and education program. MDC promotes Tree City, USA, which encourages communities to manage and allocate funds for their tree resources.

The state should continue to identify and implement programs to expand this effort, particularly on publicly held lands. As noted in the technical section of this chapter, an increase in urban tree planting is a cost effective means to offset CO₂ emissions. For example, shade tree planting in parking lots reduces excessive heat buildup that could adversely affect the local climate and air quality. An urban tree is 15 times more effective at reducing carbon dioxide production than a wildland tree, primarily due to impact on energy use for space heating and cooling.

Missouri communities, counties and other local jurisdictions own a large, although unknown, amount of land in or near urban centers. This includes land held for recreation or conservation purposes such as parks, municipal golf courses and designated green belts and open spaces. The inventory also includes lands owned for other purposes such as wastewater treatment plants, maintenance facilities and areas surrounding large institutional buildings such as detention centers, hospitals and schools. Many such areas could be planted with trees using public funds or donations.

The following are examples of options the state could pursue to increase urban tree planting:

- Develop a program to inventory available publicly-held lands that could be planted with trees and provide incentives such as cost sharing or other mechanisms.
- Encourage a tree planting and maintenance element in local planning and in plans for new school construction, land development and parking area developments.
 - Provide software and analytic support to local planners for assessing the role of urban trees in land-use planning and policy-making. Tools are available to help planners estimate the economic benefit of tree planting and preservation in averting stormwater runoff, preserving air quality, reducing summer energy expenditures and providing carbon sequestration.

- ▶ Regional and local authorities could require these elements in development plans. For example, many cities in the United States have adopted ordinances that require specified amounts of tree planting or shading in parking lots.
- Include information on landscaping in state efforts to promote or provide technical information about passive solar home design.
- Provide tax credits and other incentives to utilities to develop or expand urban tree planting programs in their service areas as energy conservation measures.
- If Missouri develops a voluntary state registry system for carbon credits as discussed in the introductory chapter of this report, the system should include a provision for registering carbon credits for tree planting in Missouri.

Monitor and Assess the Success of Expanded Education, Training, Technical Assistance, Demonstration, Incentive and Other Voluntary Programs in Promoting Sustainable Management of Missouri Forestlands

The state should develop data on Missouri's forest resources sufficient to assess the impact of forest management practices in Missouri on the sustainability of Missouri's forest resources. This could include voluntary data collection measures or legislation to establish data collection authority for developing an "information base" on forest resources.

Appendix 1 - U.S. Operating Anaerobic Methane Digesters by Digester Type

	Location	Year built	Animal type and population	Manure handling	Installed cost	Biogas end-use	Annual methane reduction (MTCE)
Covered Lagoon							
	CA	1982	Swine; 1,650 sows farrow-to-finish	Flush	\$220,000	Electricity and hot air	2,316
	CA	1984	Swine; 900 sows farrow-to-finish	Flush	\$120,000	Electricity and hot air	1,263
	CA	1986	Swine; 550 sows farrow-to-finish	Flush and gravity drain	\$75,000	Electricity and hot air	772
	VA	1993	Swine; 600 sows farrow-to-feeder	Flush and pull plug	\$85,000	Electricity	397
	NC	1997	Swine; 4,000 sows farrow-to-wean	Pull Plug	\$290,000	Electricity and hot water	1,158
	NC	1999	Swine; 400 sows Farrow-nursery	Flush	\$22,150	Flare	146
	IA	1998	Swine; 3,000 nursery pits	Pull plug	\$15,000	Flare	Never metered
	CA	1998	Dairy; 200 cows	Flush	\$150,000	Flare	149
	MS	1998	Swine; 120 pigs	Hose wash	\$19,000	Flare	17
	WI	1999	Dairy; 1,100 milkers	Scrape	\$37,300	Flare	Never metered
	WI	1999	Dairy; 1,300 milkers	Scrape	\$122,000	Flare	Never metered
Complete Mix							
	NC	1983	Caged layers; 70,000	Scrape	\$225,000	Electricity	1,129
	NY	1985	Dairy; 270 milkers	Scrape	\$500,000 ¹	Electricity and hot water	672
	PA	1985	Swine; 1,000 sows farrow-to-finish	Scrape	\$325,000	Electricity and hot water	1,210
	CT	1997	Dairy; 600 milkers	Scrape	\$450,000	Electricity	1,210
	IL	1998	Swine; 8,600 finishing hogs	Pull plug	\$152,300	Hot water and flare	1,191

	Location	Year built	Animal type and population	Manure handling	Installed cost	Biogas end-use	Annual methane reduction (MTCE)
	IA	1999	Swine; 5,000 sows farrow-to-wean	Pull plug	\$546,000	Electricity	959
	CO	1999	Swine; 5,000 sows farrow-to-wean	Pull plug	\$368,000	Electricity	1,013
I. Plug Flow-Straight Flow Configuration							
	Location	Year built	Animal type and population	Manure handling	Installed cost	Biogas end-use	CH ₄ reduction Mt CE/year*
	MI	1981	Dairy; 720 milkers	Scrape	\$150,000	Electricity	1,169
	VT	1982	Dairy; 340 milkers	Scrape	\$185,000	Electricity and hot water	1,008
	CA	1982	Dairy; 400 milkers	Scrape	\$200,000	Electricity and hot water	806
	OR	1997	Dairy; 1,000 milkers	Scrape	\$287,300	Electricity	1,129
	NY	1998	Dairy; 1,000 milkers	Scrape	\$295,700	Electricity	1,129
	MN	1999	Dairy; 1000 milkers	Scrape	\$329,851	Electricity	992
Plug Flow-Slurry Loop Configuration							
	IA	1972	Swine; 150 sows	Flush	\$20,000	Flare	Never measured
	PA	1979	Dairy; 2,000 milkers	Scrape	\$260,000	Electricity and hot water	5,107
	PA	1983	Caged layer; 70,000	Scrape	\$140,000	Electricity and hot water	753
	PA	1983	Dairy; 250 milkers	Scrape	\$120,000	Electricity and hot water	538
	CT	1997	Dairy; 200 milkers	Scrape	\$149,000	Hot water and flare	242
	MD	1994	Dairy; 450 total head	Scrape	\$500,000 ¹	Flare	349
II. Other Digester Types							
	IA	1999	Swine; 2,800 finishing hogs	Scrape	\$244,675	Hot water and flare	827

Source: EPA AgStar Program, <http://www.epa.gov/agstar/operation/bytype.html>

Appendix 2 – Factors Affecting the Accuracy of the Estimate of Forest Carbon Sequestration

In evaluating the estimates of net forest sequestration from forest growth contained in the *1990 Inventory, Trends and Projections* report and the current report, one should take into account that these estimates are subject to several sources of error that might lead to an underestimate or overestimate of net sequestration.

One of the most significant sources of error is that sequestration by wood products is not included in the estimate. Several recent studies of the role of forests and wood products in the carbon cycle at a national or global level have defined a sequence of “carbon pools” through which harvested carbon passes once it has left the ecosystem.

It seems likely that a substantial percentage of the carbon from Missouri timber harvests remains sequestered for long periods in the wood-product carbon pool. However, the data necessary to estimate the quantity of carbon sequestered in the product pool is not available at a state level. Therefore, the *1990 Inventory and Trends and Projections* reports use a simplified methodology to estimate carbon sequestration from forests that does not include the product pool.

Most of Missouri’s roundwood harvest goes into primary product categories such as saw logs, cooperage logs, veneer logs and miscellaneous categories. Much of the wood from this primary processing probably goes into secondary manufactured products, which last for a number of years, and then into landfills, where it may be sequestered for many more years.

The carbon contained in harvest residues appears less likely to be sequestered in product and landfill pools for long periods of time. About 85 percent of Missouri’s charcoal and most of its pulp derive from mill residue rather than roundwood. Most charcoal is manufactured into briquettes for combustion, although some is manufactured into specialty products for the chemical industry. Pulp from harvest residues as well as the limited amount of pulp currently derived from Missouri’s roundwood harvest goes into paper products. In general, paper products are subject to more rapid decay than solid wood.

In addition to use of a simplified methodology that does not account for product pool sequestration, another possible source for underestimates of net sequestration is the assumption that the growth rate of forest biomass will remain constant at 3 percent. This growth rate reflects past management practices. Management practices could change in ways that would increase the growth rate. As sensitivity analysis in the report indicates a 1 percent increase in forest growth rate would lead to a 33 percent increase in sequestration, other things being equal. Findings from forest inventories indicate the quality of the current forest sites will support growth rates greater than the historic 3 percent rate.

On the other hand, forest growth rate could decrease as well as increase due to such factors as maturation, such as has occurred in a number of northeastern states. Forest growth rate could also decrease if landowners were to move away from sustainable forest management practices. A 1 percent decrease in forest growth rate would decrease sequestration by about 33 percent.

Another factor that could affect net sequestration is a move toward growing and harvesting for chip mills. While an increase in pulpwood harvest could increase biomass growth rate, it also could decrease the average storage duration of carbon derived from Missouri forest harvest. In general, the paper products manufactured from pulpwood harvest are subject to more rapid decay than the solid wood products produced from Missouri’s traditional saw wood timber economy.

However, the length of time that the carbon in paper is sequestered in product and landfill pools can vary depending on several factors:

- a) Recycling can extend the period during which the carbon is stored in a product pool.
- b) Paper with high lignin content decays slowly in landfills.
- c) Some studies indicate that paper in modern landfills may escape decay for very long periods of time.

Finally, the harvest growth rate projected by the *Trends and Projections* report might be low. The only available projection of forest harvest appears in a Forest Resource study completed in 1989. This source projects a linear growth curve for forest removals. Since 1989, the growth curve for forest removals has grown steeper, following a curvilinear growth pattern. Preliminary returns from a 1997 Forest Resource study indicate the faster growth rate established in the first half of the decade will probably continue.

Missouri Action Options for Reducing Greenhouse Gas Emissions – July 2002

Chapter 6

Options to Reduce GHG Emissions from Solid Waste Management in Missouri

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Background	249
Technical Options to Reduce or Sequester Greenhouse Gases Through	
Solid Waste Management in Missouri	250
Source Reduction	250
Recycling	251
Landfill Gas Collection	256
Municipal Waste Combustion	257
Policy Options to Reduce or Sequester Greenhouse Gases Through	
Solid Waste Management in Missouri	257
Public Information and Education	257
Promote Source Reduction, Recycling and Reuse, Assigning	
Highest Priority to These Policy Options	258
Encourage Economically Sustainable Capture and Use of	
Methane Gas in Missouri Landfills	262
Consider Waste Combustion, Assigning Lesser Priority to This	
Option	263

Chapter 6 - Options to Reduce GHG Emissions from Solid Waste Management in Missouri

Background

A chapter on solid waste management is included in this study of options to reduce Missouri's greenhouse gas (GHG) emissions for three reasons.

First, Missouri's municipal solid waste landfills are an important source for emissions of methane, a highly potent greenhouse gas. Greenhouse gas inventory reports published by the Missouri Department of Natural Resources' Energy Center¹ describe how landfill methane emissions occur and estimate total statewide emissions from this source as follows:

- An estimated 6.3 million short tons carbon dioxide equivalent (STCDE) of methane was emitted from Missouri landfills in 1995. This is a midpoint estimate of emissions expressed in equivalent short tons of carbon dioxide (CO₂.)
- An estimated 5.2 million tons (STCDE) of methane is projected to be emitted from Missouri landfills in 2005. This estimate takes into account policies in place, including policies to promote recycling in Missouri. It also takes into account federal and state requirements to flare or capture methane and other landfill gases. These requirements affect about half Missouri's landfills.

Second, landfill methane represents an alternative energy source that could reduce Missouri's dependence on imported fossil fuels and reduce CO₂ emissions from fossil fuel combustion. Further discussion of landfill methane may be found in this chapter and the chapter on electric generation.

Finally, for many wastes, the materials that we dispose of represent the remains of a long series of steps including: (1) extraction and processing of raw materials; (2) manufacture of products; (3) transportation of materials and products to markets; (4) use by consumers; and (5) waste management. At virtually every step along this "life cycle," the potential exists for GHG impacts.

As the technical section of this chapter discusses in greater detail, Missouri has several options for waste management, all of which are used in the state's integrated waste management strategy. Different waste management options have different implications for energy consumption, methane emissions, and carbon sequestration.

In a study of the relative impact of various waste management options on net GHG emissions, the U.S. Environmental Protection Agency (EPA) found that source reduction generally resulted in the lowest net emissions. The reduction in energy-related emissions from the raw material acquisition and manufacturing process, and the absence of emissions from waste management, combined to reduce GHG emissions more than all other options.

The U.S. EPA study found that recycling generally has the second lowest GHG emissions. For most materials, recycling reduces energy-related CO₂ emissions in the manufacturing process (although not as dramatically as source reduction) and avoids emissions from waste management. In addition, paper recycling increases storage of forest carbon.

¹ *Inventory of Missouri's Estimated Greenhouse Gas Emissions in 1990* (Jefferson City, 1996) and *Greenhouse Gas Emission Trends and Projections for Missouri, 1990-2015* (Jefferson City, 1999).

Finally, the U.S. EPA study found that the net GHG emissions from combustion and landfilling are similar for a mixed municipal solid waste stream. The relative net emissions for a particular waste-to-energy (WTE) facility versus a particular landfill depends primarily on technology factors – that is, the efficiency of the landfill gas collection system versus the energy conversion efficiency of the WTE facility.

Technical Options to Reduce or Sequester Greenhouse Gases Through Solid Waste Management in Missouri

Introduction

It is widely understood that reducing waste is good for the environment. What most don't know is that solid waste reduction and recycling help in preventing global climate change. How? By decreasing the amount of heat-trapping greenhouse gases that are linked to everyday trash. The manufacture, distribution, and use of products – as well as management of the resulting waste – all result in greenhouse gas emissions. Waste prevention and recycling reduce greenhouse gases associated with these activities by reducing methane emissions, saving energy, and increasing forest carbon sequestration.

Missouri adopted a policy of applying an integrated waste management hierarchy in 1989 and passed legislation in 1990 that focused on alternatives to landfilling solid waste. Integrated waste management means managing waste by a combination of methods that includes waste reduction, materials reuse, recycling, composting, incineration with energy recovery and landfilling. These alternatives are arranged in a hierarchy that maximizes waste reduction and uses incineration and landfilling only as needed for those wastes that cannot feasibly be recovered.

Since the mid-1950s, Missouri has made a transition from unhealthy open dumps to today's engineered, permitted and regulated landfill sites. Integrated solid waste management planning, which recognizes that some "wastes" may actually be resources, is widely practiced throughout the state. Following are discussions regarding strategies that reduce GHG emissions from the waste sector: source reduction and recycling, composting, landfill gas collection and municipal waste combustion.

Source Reduction

Source reduction reduces energy use in two ways: first, by decreasing the amount of raw materials used in packaging or product design, the energy use associated with raw material extraction is reduced. Second, reducing material use in manufacturing products and packaging also reduces the volume of materials that must be managed as waste. Reduction can be achieved by designing products or packaging to reduce the quantity of materials used, reducing the toxicity of materials used to facilitate reuse and recycling, lengthening the lives of products to postpone disposal and managing non product organic wastes (e.g., food scraps and yard trimmings) through on-site composting or other alternatives to disposal (e.g., leaving grass clippings on the lawn). Examples of source reduction include "light weighting" by making packages thinner, and double-sided photocopying. Once generated, wastes are best handled through reuse, recycling and composting.

Reduction can be measured by examining our waste generation rates. Factors that contribute to our generation rate include excessive packaging, the elimination of most refillable containers, tax incentives favoring virgin materials, a throwaway approach to goods consumption and a scarcity

of goods that can be repaired instead of having to be discarded. To reduce the amount of waste generated, programs must be developed and implemented that will cause changes in business practices and consumer habits.

Public information campaigns and educational programs can encourage purchasing products with the least amount of packaging necessary for safe product delivery, repairing durable goods instead of replacing them and bulk purchasing. It is difficult to quantify the amount of waste reduction being practiced today. There are programs implemented by the department and the solid waste management districts that, when successful, do result in a reduction in the generation of waste. One particularly effective technique that increases waste reduction, as well as reuse, recycling and composting, is unit-based pricing. This technique, also called “pay-as-you-throw,” refers to a solid waste collection system that bases the collection fee on the amount of waste set out for disposal. Each customer has an economic incentive to reduce generation of waste or divert more materials to recycling and composting operations. According to a U.S. EPA tally, in 1999 ten communities in Missouri were using unit-based pricing for residential waste disposal.²

The department promotes this technique through the distribution of guidance materials, workshops and grant funding for local implementation. To date, two statewide waste recovery and recycling grants have funded “pay-as-you-throw” projects.

Source reduction reduces fossil fuel combustion associated with product manufacturing and as a result, GHGs are reduced. Source reduction also decreases the amount of organic waste that is landfilled, thereby decreasing landfill methane emissions. Source reduction reduces emissions of conventional pollutants associated with fossil fuel combustion. Source reduction can eliminate energy emissions associated with manufacturing materials. Source reduction also reduces energy used to manage wastes.

Recycling

Although waste reduction is at the top of the hierarchy model, today’s products, lifestyles and business practices will continue to cause a great deal of waste material to be generated at home, work or leisure. Recycling is the waste management option that generally diverts the greatest amount of material from the waste stream. In Missouri, as in its neighboring states, landfill costs have not risen as significantly as in some parts of the United States, making it more critical to use careful planning to create sustainable programs. For some materials, both the distance to markets and fluctuations of the markets make recycling a risky venture. However, Missouri has made progress and continues to increase recycling opportunities across the state. The number of communities with access to recycling services has risen from 51 in 1989 to 394 in 1998 as seen in Figure 1.

² Description and results of the tally are available at <http://www.epa.gov/epaoswer/non-hw/payt/comminfo.htm>.

Recycling Collection Services in Missouri

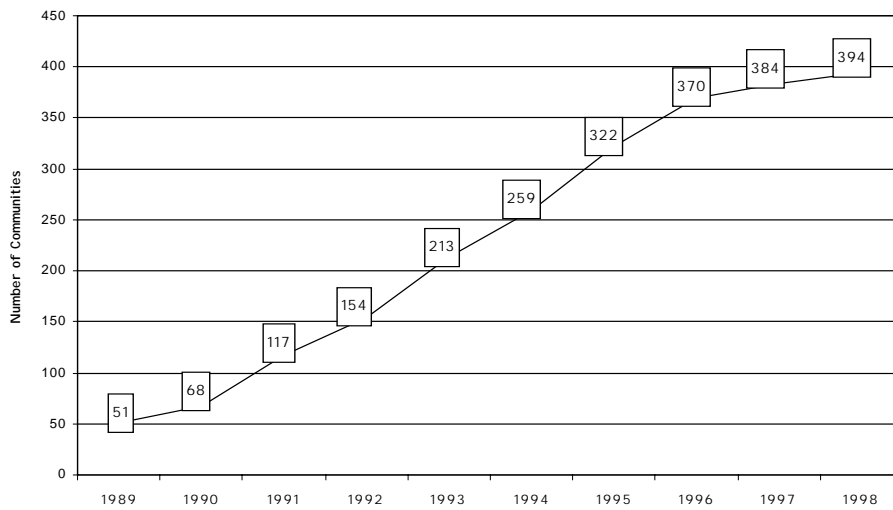


Figure 1

The department has estimated that for the calendar years 1998, 1999 and 2000, a total of 6,406,914 tons of municipal solid waste were recycled. Municipal solid waste is waste generated in households, commercial establishments, institutions, and light industries. The U.S. EPA standard recycling methodology was used to determine this number. Figure 2 shows the impact those recycled materials had on GHG reduction, energy use and energy cost.

Impact of Recycling on GHG Reduction, Energy Use and Energy Cost



Figure 2

These figures were determined by using a spreadsheet model titled Estimating the Environmental Benefits of Recycling, August 1999, developed by Edward Boisson of the Northeast Recycling Council (see Appendix I). Detailed information for each of the referenced years is included with Appendix I as well.

The effects of recycling on energy use and GHG emissions are similar to the effects noted for source reduction. Recycling reduces fossil fuel combustion associated with product manufacturing and as a result, GHGs are reduced. Recycling decreases the amount of organic waste that is landfilled, thereby decreasing landfill methane emissions. Recycling reduces emissions of conventional pollutants associated with fossil fuel combustion, eliminates emissions associated with manufacturing materials and also reduces energy used to manage wastes. Further, recycling often reduces the energy demand associated with raw materials acquisition and manufacturing with virgin inputs.

Recycling - Energy Facts

- ☞ It requires 95 percent less energy to make aluminum from recycled material than to make it from bauxite, the primary ore.
- ☞ Each year, steel recycling saves energy equivalent to providing electric power to about one-fifth of the households in the United States (or about 18 million homes) for one year.
- ☞ Recycled paper saves 60 percent of the energy used to make paper from wood pulp.

Composting

Composting involves the management of organic wastes through on-site collection. Composted material is ultimately applied for useful purposes. Compost may be made in a backyard, from one household's organic waste, or centrally, using wastes from many households. Composting is suitable for organic materials, particularly food scraps and yard trimmings. Aerobic composting avoids the methane emissions associated with anaerobic landfills. GHG Reduction Potential: Composting is an attractive GHG reduction strategy for organics. By composting organics, landfill methane emissions from these materials are avoided. However, composting can lead to emissions of sulfur and volatile organic compounds (VOCs) when the compost pile becomes anaerobic, or depleted of oxygen.

Yard Waste Composting

In Missouri, the majority of composting activities address yard waste, which since 1992 has been banned from disposal in landfills. Many of the same policies used to promote recycling are employed in promoting composting and mulching techniques. The solid waste management districts reported that citizens of 303 communities had access to yard waste management options in 1998 (Figure 3). Although the yard waste disposal ban stimulated growth in composting programs, in many parts of the state, open burning is the current management method for yard wastes.

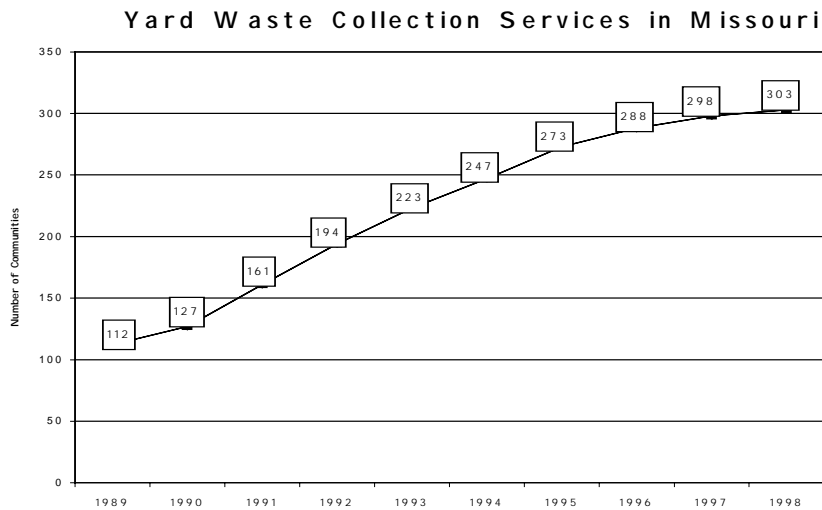


Figure 3

Composting Other Organics

Composting can also be utilized to manage other organic components of the waste stream. Homeowners, businesses and institutions are encouraged to use on-site composting to manage the food wastes they generate. The department also encourages large scale composting of food wastes, paper, biosolids and some animal wastes. Recent changes to the regulations for solid waste processing facilities provide some permit exemptions for composting these materials.

There has been minimal interest in Missouri for biosolids composting (composting sewage sludge or co-composting sewage sludge with other organics). This management option is being considered as land available for direct application decreases. The department's Water Pollution Control Program designates application rates and site specifications. If proper design and operation standards are followed, biosolids can be co-composted with yard waste and other organic waste streams to create a usable soil amendment.

Although there has been some interest in food waste composting, the majority of implemented programs has been small-scale, such as the placement of worm bins in schools or offices.

Recently, Reeds Spring High School began operating a state-of-the-art in-vessel composting system. Along with other equipment, the system is expected to help the school district recycle 90 percent of its generation of food, paper, cardboard and aluminum container wastes.

The Department of Natural resources provided a grant of \$100,000 and Solid Waste Management Region N provided \$15,000 in grants toward the project. Local sources have provided \$37,500 in matching funds and various support equipment for the project.

Since early January 2001, the in-vessel composter has been taking three feedings a week of the school district's 900 pounds-per-day generation of food wastes and 100 pounds per day of paper wastes. There are five school buildings diverting these wastes from disposal in landfills. The district expects to recover its investment by savings in disposal costs and through sale of its compost and other recycled products. Silver Dollar City and JC Penny have donated a beverage can crusher and cardboard baler to the school district's recycling/composting project.

Air and water quality concerns are also addressed with the installation of the composting system. Wash and rinse water is recycled for reuse on site and a holding tank is provided for collection of wastewater for eventual treatment. A bio-filter that utilizes compost for odor control is also being used. The composter itself operates on a vacuum so odors are virtually eliminated on site.

Immediate plans for the compost generated are for use in the high school's botany and greenhouse classes on campus and for various landscaping needs among the district's buildings and grounds.

A small number of facilities that compost the entire solid waste stream are in operation in the United States. This process, generally called municipal solid waste composting, requires a processing facility permit in Missouri. To date, no permit applications have been received for this type of facility.

Landfill Gas Collection

Greenhouse gases are produced as the organic materials buried in landfills decompose. Landfill gas may be collected through a system of vertical pipes throughout the landfill, and then flared or combusted for energy recovery. Landfill gas collection reduces landfill methane emissions. When landfill gas is combusted for energy (rather than flared), electric utility GHG emissions are reduced.

While landfill gas recovery is desirable to reduce GHG emissions, it is the organic portion of the waste stream that produces methane and other GHGs. There is an argument that programs encouraging landfill gas collection could indeed be detrimental to recycling efforts of the organic portion of the waste stream (e.g. food wastes, paper wastes). As noted earlier, yard waste has been banned from disposal in Missouri landfills; consequently, landfill gas recovery programs should not affect yard waste composting.

At present methane is collected for energy recovery from two Missouri landfills located in St. Louis, the Superior Oak Ridge Landfill and Fred Weber Inc. landfill.

The Superior Oak Ridge Landfill in St. Louis recently began piping methane to the nearby Chrysler plant.

Methane is collected from the Fred Weber Inc. landfill to provide heat to the Pattonville High School. The Pattonville Project started officially in January 1997, and is expected to save the district \$30,000 annually (at 1997 natural gas prices), and provide heat for the school for at least 40 years.

A 3,200-foot pipeline takes the gas to the school property. Fred Weber, Inc. at no cost, provided the first 2,000 feet to the school. The final 1,600 feet of pipeline and converting the school boiler to methane use cost the school district \$150,000. A 2 percent loan from the Department of Natural Resources and a \$25,000 grant from St. Louis County covered this cost.

Gas is collected through a series of perforated pipes that extend from the surface to near the bottom of the landfill. The interconnected grid of pipes is then connected to a blower system that provides the gas directly to the school. A garlic odor is injected to alert people to possible leaks, but the gas itself does not need to be upgraded for use.

Municipal Waste Combustion

Municipal waste combustion generally produces electricity, using “fuel” that is primarily biogenic. Thus, most CO₂ emissions from combusting waste are not counted as greenhouse gases, and the electricity produced displaces utility fossil fuel-fired electricity. Additional explanation of this premise can be found in Chapter One.

Waste combustors generally use mass-burn combustion technology. In the United States, most combustors produce steam from the heat of combustion, which can generate electricity.

Compared to landfills without gas collection systems, combustors have lower net GHG emissions because they do not emit methane, and the electricity they generate displaces CO₂ that results from burning fossil fuels at utilities. Compared to landfills with gas collection systems, GHG reductions are minimal. Combustors generating electricity are able to offset some CO₂ emissions from electric utilities.

Energy recovery, sometimes called waste-to-energy, follows waste reduction, reuse, recycling and composting in the hierarchy of waste management options. Increases in landfilling costs, coupled with higher costs for fossil fuels, have made energy recovery from solid waste more feasible in some parts of the country. In addition to producing energy, waste-to-energy plants reduce the volume of waste left for disposal.

Missouri has no permitted public incinerators that use mixed waste from residential and commercial sources for fuel. A number of universities and small communities have used pelletized paper waste in their boilers to produce heat. Waste tires are co-fired with coal at the University of Missouri-Columbia power plant, providing electricity and heat for the campus.

Policy Options to Reduce or Sequester Greenhouse Gases Through Solid Waste Management in Missouri

The U.S. EPA has ranked strategies for municipal solid waste management, with source reduction (including reuse) the most preferred method, followed by recycling and composting, and, lastly, disposal in combustion facilities and landfills.³

In general, this section emphasizes options for reducing GHG emissions from solid waste according to their position in this hierarchy of solid waste management practices. Reducing the amount of solid waste generated that is destined for landfills is a primary goal of solid waste management programs in Missouri and should receive primary policy emphasis.

Continue to Inform and Educate State and Local Policy Makers, Students and the General Public Regarding Opportunities and Benefits for Improving Solid Waste Management in Missouri

This effort should include information and education on benefits, practical techniques, technical opportunities and policy options to promote source reduction, recycling, composting and landfill gas capture.

³ Source: <http://www.epa.gov/epaoswer/non-hw/muncpl/facts.htm>. See John Schall, *Does the Solid Waste Management Hierarchy Make Sense? A Technical, Economic & Environmental Justification for the Priority of Source Reduction and Recycling*, Yale Working Papers, 1992

The state could develop an information and education network including government, educational and not-for-profit organizations to coordinate and enhance this information and education effort.

The state's Solid Waste Management Program should continue to provide technical information to Missouri's solid waste management districts, counties and cities.

Promote Practices that Reduce the Creation of Solid Waste in Missouri and Provide Feasible Alternatives to Disposing of Waste in Missouri Landfills, and Assign Highest Priority to These Policy Options

Senate Bill 530, signed into law in 1990, set a 40 percent solid waste reduction goal for district solid waste management plans in Missouri.

Since 1990, the flow of solid waste to landfills in Missouri has been reduced by 38 percent. This reduction was prompted by mandates under the Solid Waste Law that banned the landfilling of major appliances, whole tires, waste oil and lead batteries effective Jan. 1, 1991. Under the same law, yard waste was banned effective Jan. 1, 1992.

Also effective in moving Missouri toward a 40 percent reduction in solid waste disposal by 1998 was the establishment of a Solid Waste Management Fund and four associated grant programs that have supported the creation and implementation of local solid waste management initiatives.

Current solid waste statistics show that progress has been made. However, Missouri's population and economic base have continued to grow, accompanied by increased generation of solid waste. Aggressive action is required to stem this increase in waste generation and achieve further diversion of the waste flow through reduction, reuse, and recycling.

Buying recycled products remains the most essential factor in closing the recycling loop. Efforts are underway to increase recycling opportunities in Missouri's rural areas and encourage cooperative marketing techniques that will eventually develop stronger markets for recovered materials. As long as landfill disposal costs in Missouri remain lower than the cost of recycling, it will continue to be a challenge to increase the percentage of waste being diverted from landfills.

The state should continue to promote an integrated approach to the management and reduction of solid waste using a combination of alternatives. This approach should continue to be an integral part of the solid waste management planning process carried out by the state's Solid Waste Management Program and Solid Waste Management Districts.

Promote Source Reduction as a Solid Waste Management Strategy in Missouri

Source reduction refers to any change in the design, manufacture, purchase, or use of materials or products (including packaging) to reduce their amount or toxicity before they become municipal solid waste. Source reduction also refers to the reuse of products or materials.

Source reduction, including reuse, has multiple benefits in addition to a reduction in GHG emissions, including resource conservation and reductions in waste disposal and handling costs.

Because most products are manufactured in facilities located throughout the United States, individual states cannot readily take a lead role in promoting source reduction at the manufacturing level. Manufacturing source reduction is best achieved through federal sponsorship of voluntary agreements by industrial groups.

The state could encourage source reduction by sponsoring public information campaigns and educational programs explaining and promoting business practices and consumer habits that reduce sources of solid waste. Information and education campaigns could encourage practices such as bulk purchasing, repairing durable goods instead of replacing them and purchasing products with the least amount of packaging necessary for safe product delivery.

Promote Recycling as a Solid Waste Management Strategy in Missouri

As noted in the introduction to this chapter, a U.S. EPA study of the GHG impact of various waste management technologies found that recycling generally has the second lowest GHG emissions, second only to that achievable from source reduction.

Promote Recycling of Waste Products for Which a Viable Market Exists

Several strategies for accomplishing this, including information and education, technical assistance, financial assistance to selected projects and implementation of unit-based pricing, are discussed throughout this chapter.

Promote the Expansion of Viable Markets for Recycled Waste Products

For example, the state could promote and provide technical or financial assistance for cooperative marketing, in which several communities pool their resources in order to create a stronger, more regional market for recycled materials.

Promote Reuse as a Solid Waste Management Strategy in Missouri

The state should promote recycling or reuse of construction and demolition waste. The Missouri Waste Composition Study, conducted by Midwest Assistance Program Inc. in 1996 and 1997, estimated that construction and demolition waste comprised as much as 13 percent of the Missouri waste stream. State grants could be focused on this category of waste.

Solid Waste Management Districts and municipal governments could sponsor Product Reuse Centers for products such as waste paint.

Promote Composting of Yard Waste and Other Organic Materials in Missouri

Many of the same policies used to promote recycling are employed in promoting composting and mulching techniques. The primary method for promoting composting and mulching is through informational and public education efforts.

One factor that affects the level of composting in a community is the level of open burning that occurs in the community because open burning of yard or agricultural waste is an alternative to composting. Open burning is a local issue in Missouri. Policies on open burning and the frequency of burning vary widely among Missouri communities.

Continue to Provide Information and Technical Assistance on Proper Composting Techniques for Residential Yard Waste and Other Organic Waste

Information and education at all levels, from homeowners to elementary school students, is the key approach for promoting residential composting.

While yard waste is likely to continue as the largest single component of residential compost piles, residential sector composters can also include food wastes. As noted in the technical section, the failure to supply sufficient oxygen to a compost pile can lead to emissions of sulfur and VOCs if the compost pile becomes depleted of oxygen.

Encourage and Promote an Expansion of Safe, Environmentally Responsible Composting by Businesses and Institutions in Missouri

Composting can be utilized to manage many organic components of the waste stream. The state should help businesses, institutions and local jurisdictions identify opportunities and proper management techniques for:

- Composting food wastes generated by businesses and institutions such as restaurants, schools, hospitals and prisons.
- Large scale composting of food wastes, paper, biosolids and some animal wastes.
- Biosolids composting, that is, composting sewage sludge or co-composting sewage sludge with other organics.

As in the residential sector, the state should continue to provide technical information on opportunities and proper techniques for composting by businesses and institutions in Missouri. In addition, the state should consider the following actions.

Continue to Publicize and Provide Incentives for Large-Scale and Innovative Composting Initiatives by Schools and Other Public Institutions in Missouri

To date, most institutional programs for food waste composting in Missouri have been small scale. The state should facilitate and provide incentives for projects that demonstrate opportunities for larger-scale efforts.

For example, with assistance from the state and the solid waste management district, Reeds Spring High School recently established a state-of-the-art in-vessel composting system that is expected to help the school district recycle 90 percent of its generation of food, paper, cardboard and aluminum container wastes.

Review Regulations that Would Govern Composting by Businesses and Institutions, Identify any Regulatory Barriers that May Exist, Consider Changes that Would Remove These Barriers and Monitor the Results of Any Regulatory Change

Recent changes to the regulations for solid waste processing facilities provide some permit exemptions for composting these materials.

Other regulatory areas discussed in the technical section of this chapter include:

- Processing facility permits for municipal solid waste composting.
- Regulations that govern co-composting of biosolids with yard waste and other organic waste streams to create soil amendments.

Provide Financial Assistance for Projects that Result in a Decrease in the Amount of Materials Disposed of and an Increase in the Amount Reused

For example, the Department of Natural Resources and the Solid Waste Management Region provided grant money to assist the Reeds Spring High School composting system described earlier. The school district provided matching funds for the project.

Encourage Communities to Base Their Solid Waste Collection Fees on Volumetric or Unit-Based Pricing Mechanisms that Account for the Full Cost of Solid Waste Disposal

As discussed in the technical section of this chapter, collection fees based on the amount of waste set out for disposal provide an incentive to businesses and consumers to find ways to reduce waste destined for landfills. Coupled with convenient recycling opportunities, unit-based pricing has been shown to dramatically increase the amount of waste diverted from landfills.

The state should continue to promote unit-based pricing through the distribution of guidance materials, sponsoring workshops and providing grant funding for local implementation. To date, two statewide waste recovery and recycling grants have funded “pay-as-you-throw” projects.

Participate In and Promote Partnerships to Achieve Waste Reduction, Reuse, Recycling and Composting

Achieve Waste Reduction and Recycling in State Facilities

Successful implementation of waste reduction, recycling and composting projects in state facilities would have a direct impact on the amount of waste going to landfills. In addition, such projects would increase the state’s credibility and ability to provide leadership in state waste reduction efforts.

Continue to Support the “Choose Environmental Excellence” Initiative in Missouri and Encourage its Establishment in Additional Communities in the State

Choose Environmental Excellence is a partnership of business, government and private citizens acting together to improve environmental awareness and actions in daily choices. Initiated by a non-profit environmental organization in Kansas City in 1994, the campaign is now established in Kansas City, St. Louis and several other Missouri communities.

The Missouri Department of Natural Resources and the Environmental Improvement and Energy Resources Authority (EIERA) are members of the initiative’s statewide steering committee. The EIERA is providing funding for the statewide Environmental Excellence Campaign. A number of not-profit and civic groups are also members of the steering committee.

The Environmental Excellence Campaign provides education, resources and support about waste reduction, recycling, air and water quality issues, transportation, energy and resource conservation. Many of the actions taken have focused on solid waste reduction or recycling.

Examples of achievements by business partners in Environmental Excellence include:

- Hallmark Cards’ success in reducing its waste stream by 69 percent over the last seven years.
- Allied Signal Federal Manufacturing and Technologies’ success in eliminating 4,000 plastic foam cups per day by providing free reusable mugs to its employees. Allied also recycled 3,300 tons of asphalt chunks from its rebuilt parking lot.

- General Motors (St. Louis) success in establishing an award-winning Environmental Management System and fostering voluntary recycling actions among employees that saved the equivalent of about 3.9 million gallons of oil over three years.

Initiate a Coordinated Effort to Identify and Implement Composting Projects in State Facilities

It is likely that there is potential for composting food wastes at a number of public institutions such as state universities, hospitals and prisons. A coordinated effort could take advantage of existing networks among administrators and facility managers of these institutions.

The State Could Participate in U.S. EPA's Waste Wise Program and Encourage Other Missouri Institutions and Businesses to Participate

Waste Wise could provide a vehicle for state leadership in the effort to reduce institutional waste destined for landfills.

WasteWise is a voluntary program through which organizations eliminate municipal solid waste. The program that allows partners to design their own solid waste reduction programs tailored to their needs. Participants may include state and local governments, institutions such as hospitals and universities, businesses and not-for profit organizations. The state could participate in U.S. EPA's Waste Wise Program, and encourage other Missouri institutions and businesses to participate.

The WasteWise Program provides free technical assistance to help participating organizations develop, implement, and measure waste reduction activities; offers publicity to organizations that are successful in reducing waste; and provides networking opportunities for organizations to share waste reduction ideas and success stories.

Encourage Economically Sustainable Capture and Use of Methane Gas in Missouri Landfills

As described in the technical section of this chapter, capturing or flaring methane gas at landfills reduces total emissions of methane, a highly potent greenhouse gas. Capturing the methane to use as a heating source or a source for generating electricity further reduces total GHG emissions by offsetting fossil fuel use that would otherwise occur.

State government could continue to assess opportunities to establish economically sustainable methane gas collection systems at Missouri landfills, and assist in the creation of economically sustainable landfill methane projects in Missouri by undertaking the following actions:

- Provide technical information and assistance to landfill operators who wish to explore opportunities to capture methane gas for energy use.
- Help landfill gas-to-energy (LFGTE) developers find financing, apply for state and federal grants, and negotiate sometimes-complex state and federal environmental regulations.
- Consider providing financial incentives to help initiate projects that have long-term technical and economic viability.
- Promote landfill methods that facilitate future waste recovery and methane capture.

- Support the U.S. EPA Landfill Methane Outreach Program (LMOP). LMOP is a voluntary assistance and partnership program that helps facilitate and promote the use of landfill gas as a renewable energy source. The LMOP builds partnerships between state agencies, industry, energy service providers, local communities, and other stakeholders. Missouri could encourage landfill operators and other potential stakeholders to participate.

The technical section of this report describes one project that is in place, a cooperative arrangement between the Fred Weber Inc. landfill and Pattonville High School that is expected to provide heat for the school for at least 40 years.

The Newton County Landfill in southeast Missouri is the site of a second possible LFGTE project. The landfill's board is exploring the economic feasibility of installing equipment to make use of the billion Btu/day that site generates.

Consider Waste Combustion as an Approach to GHG Reduction in Missouri, but Assign Lesser Priority to this Option

Waste combustion in waste-to-energy (WTE) projects should be assigned lower priority as an approach to GHG reduction in Missouri than waste reduction, reuse, recycling and composting. However, if the only alternative is landfilling, the state should support WTE projects that meet multiple public policy goals including reduction of net GHG emissions.

As described in the technical section, WTE projects in which organic materials are burned for energy generally result in the modest reduction of net GHG emissions. In other cases, such as combustion of plastics, WTE projects may result in an increase in net GHG emissions. In any case, the project's impact on net GHG emissions should be a secondary factor in determining state support for a WTE project.

Appendix I: Estimated Reductions in Missouri Greenhouse Gas Emissions from Recycling

	Tons recycled for select categories	Net GHG assoc'd with recycling (MTCE)	Net GHG if all disposed (MTCE)	Net GHG reduction from recycling (MTCE)
Year 1998				
Unclassified Paper	1,131,053	(757,806)	65,724	823,529
Aluminum Cans	109,247	(423,944)	3,005	426,949
Steel Cans	158,127	(90,575)	4,349	94,924
Ferrous Scrap Metal	55,988	(32,070)	1,540	33,610
Glass	119,335	(9,461)	3,282	12,744
HDPE	27,244	(9,951)	749	10,701
PET	22,820	(14,190)	628	14,817
Yard Trimmings	378,197	-	10,402	10,402
Total	2,002,011	(1,337,996)	89,679	1,427,675
Year 1999				
Unclassified Paper	1,144,991	(767,144)	66,533	833,677
Aluminum Cans	93,178	(361,587)	2,563	364,149
Steel Cans	159,118	(91,142)	4,376	95,519
Ferrous Scrap Metal	55,690	(31,899)	1,532	33,431
Glass	117,960	(9,352)	3,244	12,597
HDPE	27,034	(9,875)	744	10,618
PET	20,994	(13,054)	577	13,632
Yard Trimmings	380,745	-	10,472	10,472
Total	1,999,710	(1,284,053)	90,042	1,374,095
Year 2000				
Unclassified Paper	1,398,529	(937,014)	81,266	1,018,281
Aluminum Cans	100,005	(388,079)	2,751	390,830
Steel Cans	174,709	(100,073)	4,805	104,878
Ferrous Scrap Metal	60,517	(34,664)	1,664	36,328
Glass	129,938	(10,302)	3,574	13,876
HDPE	30,439	(11,118)	837	11,956
PET	23,697	(14,735)	652	15,387
Yard Trimmings	389,579	-	10,715	10,715
Total	2,307,413	(1,495,986)	106,264	1,602,250

Sources: ➤ Missouri MSW Summary

➤ U.S. EPA, Revised "WARM" model. June, 1999. Available online at:
<http://www.epa.gov/epaoswer/non-hw/muncpl/ghg/>.

Glossary

Glossary

Aerosol: Particulate material, other than water or ice, in the atmosphere.

Anaerobic fermentation: Fermentation that occurs under conditions where oxygen is not present. For example, methane emissions from landfills result from anaerobic fermentation of organic waste in the landfills.

Anthropogenic: Relating to the influence of human beings on nature. For instance, "anthropogenic" emissions of greenhouse gases are emissions resulting from human activities such as burning gasoline in motor vehicles or burning coal to generate electricity

Atmosphere: The envelope of air surrounding the Earth and bound to it by the planet's gravitational attraction.

Biomass: The amount, generally measured in tons, of organic living material in a unit of the Earth's surface such as one acre. The term may be used to indicate any carbon-containing animal and plant matter.

British thermal unit (Btu): A measure of the energy content of different fuels. The use of a common measure of energy makes it possible to add or compare fuels. For example, a barrel of motor gasoline contains 5.25 million Btus of energy, about as much as a quarter ton of coal.

Capacity: The amount of electric power delivered or required for which a generator, turbine, transformer, transmission circuit, station or system is rated by the manufacturer.

Carbon cycle: The continual circulation of carbon between the atmosphere, soil and rocks, oceans and living plants and animals. Carbon, a chemical element, is a constituent of all living matter. One form in which carbon resides in the atmosphere is carbon dioxide (CO₂).

Carbon source and carbon sink: Terms used to describe the exchange of carbon in the carbon cycle. For instance, when wood is burned, producing CO₂, the carbon "source" is biomass and the "sink" is the atmosphere.

Carbon monoxide (CO): A molecule comprised of one atom of carbon and one atom of oxygen. An odorless, invisible gas, it is created when carbon-containing fuels are burned incompletely. It is not a greenhouse gas, but it is short-lived and often transforms into CO₂. It has harmful effects on human health.

Carbon dioxide (CO₂): A molecule made up of one atom of carbon and two atoms of oxygen. Sources include respiration (breathing) in animals and the burning of organic matter or fossil fuels. Plants use CO₂ in the process of photosynthesis.

Chlorofluorocarbons (CFCs): A family of inert non-toxic and easily liquefied chemicals used in refrigeration, air conditioning, packaging, and insulation or as solvents or aerosol propellants. Because they are not destroyed in the lower atmosphere, they drift into the upper atmosphere where their chlorine components destroy ozone.

Climate change: Long-term fluctuations in temperature, precipitation, wind and all other aspects of the climate. Over thousands of years, climate change occurs naturally. Controversy centers over whether humans are now causing climate to change over relatively short periods of time such as one to two human generations.

Coalification: The geologic process which results in the formation of coal.

Demand-side management: The planning, implementation, and monitoring of utility activities designed to encourage consumers to modify patterns of electricity usage, including the timing and level of electricity demand. It refers only to energy and load-shape modifying activities that are undertaken in response to utility-administered programs. It does not refer to energy and load-shape changes arising from the normal operation of the marketplace or from government-mandated energy-efficiency standards. Demand-Side Management (DSM) covers the complete range of load-shape objectives, including strategic conservation and load management, as well as strategic load growth.

Enteric fermentation: Fermentation that occurs in the intestines. For example, methane emissions produced as part of the normal digestive processes of ruminant animals is referred to as "enteric fermentation."

Fossil fuels: Fuel resources (coal, oil and natural gas) embedded in the earth's crust that were created from the bodies of animals and plants by geologic processes lasting millions of years. Because they were created from organic matter, they contain carbon. When they are burned as fuels, this carbon is released as CO₂.

Global warming potential (GWP): The concept of the Global Warming Potential has been developed for policy-makers as a measure of the possible warming effect on the surface-troposphere system arising from the emissions of each gas relative to CO₂.

Global warming: A popular term for climate change that may result from anthropogenic emissions of greenhouse gases. In the "global warming" scenario, temperature around the globe rises several degrees in a short period of time.

Greenhouse effect: Describes the role of greenhouse gases in trapping heat, thereby keeping the Earth's surface warm enough to sustain life as we know it. Scientists agree that the greenhouse effect is real. Controversy centers over the degree to which human activities are increasing concentrations of greenhouse gases in the atmosphere, thereby increasing the amount of heat trapped and affecting climate.

Greenhouse gases: Those gases--such as carbon dioxide, methane, nitrous oxide and ozone--that let radiation from the sun reach the earth but trap outgoing heat. Their action is analogous to that of glass in a greenhouse.

Hydrochlorofluorocarbons (HCFCs): HCFCs are essentially chlorofluorocarbons (CFCs) that include one or more hydrogen atoms. The presence of hydrogen makes the resulting compounds less stable, and as a result they have shorter atmospheric lifetimes than CFCs and less likely to drift into the upper atmosphere where their chlorine components would destroy ozone. They are popular interim substitutes for CFCs, but international agreements have slated HCFCs for

elimination by 2030. Like CFCs, HCFCs are potent greenhouse gases; however, they have weaker indirect cooling effects than CFCs.

Hydrofluorocarbons (HFCs): HFCs are essentially hydrochlorofluorocarbons (HCFCs) without the chlorine. Because they do not destroy ozone, they are widely used as substitutes for CFCs and HCFCs. Although HFCs do not deplete ozone, they are powerful greenhouse gases and lack the indirect cooling effects of CFCs and HCFCs. For example, HFC-23 has a GWP of 10,000.

Kilowatt (kW): One thousand watts.

Kilowatthour (kWh): One thousand watthours.

Mcf: One thousand cubic feet.

Megawatt (MW): One million watts.

Megawatthour (MWh): One million watthours.

Methane (CH₄): A molecule made up of one atom of carbon and four atoms of hydrogen. Methane is a greenhouse gas which contributes about 10 percent of Missouri emissions and 18 percent of global emissions. Anthropogenic sources of methane include wetland rice cultivation, enteric fermentation by domestic livestock, anaerobic fermentation of organic wastes, coal mining, biomass burning, and the production, transportation, and distribution of natural gas.

Nitrogen oxides (NO_x): NO_x refers collectively to NO, a molecule made up of one atom of nitrogen and one atom of oxygen, and NO₂, a molecule made up of one atom of nitrogen and two atoms of oxygen. NO_x is created in lightning, in natural fires, in fossil-fuel combustion, and in the stratosphere from N₂O. It plays an important role in the global warming process due to its contribution to the formation of ozone (O₃).

Nitrous oxide (N₂O): A molecule made up of two atoms of nitrogen and one atom of oxygen. Nitrous oxide is a greenhouse gas which contributes about two percent of Missouri emissions and five percent of global emissions. Nitrous oxide is produced from a wide variety of biological and anthropogenic including application of nitrogenous fertilizers, consumption of fuel and various production processes such as manufacture of nitric acid.

Non-methane volatile organic compounds (NMVOCs): NMVOCs are frequently divided into methane and non-methane VOCs (see definition of Volatile Organic Compounds). NMVOCs include compounds such as propane, butane and ethane.

Ozone (O₃): A molecule comprised of three atoms of oxygen. Ozone (O₃) exists in both the lower atmosphere (troposphere) and upper atmosphere (stratosphere). In the troposphere, ozone is an ingredient of smog. However, in the stratosphere, it provides a protective layer that shields the Earth from ultraviolet radiation.

Ozone depletion: Scientists generally agree that certain manufactured chemicals such as chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) remove ozone from the stratosphere, where it normally provides a protective shield from ultraviolet radiation. Collectively, these chemicals are called Ozone Depleting Compounds (ODCs). The removal of

ozone is called "ozone depletion" and is a separate policy issue that should not be confused with "climate change" or "global warming." The two issues are often discussed together because several ODCs are also potent greenhouse gases.

Perfluorinated carbons (PFCs): PFCs are powerful greenhouse gases whose molecules consist of carbon and fluorine atoms. PFCs are emitted during electrolytic reduction of alumina in the primary reduction process.

Sequestered carbon: Carbon that is "trapped" in some part of the carbon cycle other than the atmosphere. For example, the carbon content of coal is sequestered until the coal is burned and carbon returns to the atmosphere as CO₂. Plants sequester carbon when they convert CO₂ to plant material.

Stratosphere: Region of the upper atmosphere extending upward from an altitude between six and nine miles altitude to an altitude of about 30 miles.

Trace gas: A minor constituent of the atmosphere. The most important trace gases contributing to the greenhouse effect include water vapor, carbon dioxide, ozone, methane, ammonia, nitric acid, nitrous oxide, and sulfur dioxide.

Troposphere: The inner layer of the atmosphere, extending upward to an altitude of six to nine miles. Within the troposphere, there is normally a steady decrease of temperature with increasing altitude. Nearly all clouds form and weather conditions occur within the troposphere.

Volatile organic compounds (VOCs): Volatile organic compounds along with nitrogen oxides are participants in atmospheric chemical and physical processes that result in the formation of ozone and other photochemical oxidants. The largest sources of reactive VOC emissions are transportation sources and industrial processes. Miscellaneous sources, primarily forest wildfires and non-industrial consumption of organic solvents, also contribute significantly to total VOC emissions.

Wires charge: A broad term which refers to charges levied on power suppliers or their customers for the use of the transmission or distribution wires.

Technical Review Distribution

Distribution of copies for technical review

Earlier drafts of this report were distributed for review to the following organizations and agencies.

AmerenUE

Associated Electric Cooperative, Inc.

Associated Industries of Missouri

Audubon Council of Missouri

Bridging the Gap

Central Electric Power Cooperative

Coalition for the Environment

Heartland Renewable Energy Society

Kansas City Power & Light

Laclede Gas Company

League of Women Voters of Missouri

Metropolitan Energy Center

Missouri Botanical Garden – Gateway Center for Resource Efficiency

Missouri Department of Agriculture

Missouri Department of Conservation

Missouri Department of Economic Development

Missouri Department of Health

Missouri Department of Insurance

Missouri Department of Natural Resources-Air Pollution Control Program

Missouri Department of Natural Resources-Division of State Parks

**Missouri Department of Natural Resources-Geological Survey
and Resource Assessment Division**

Missouri Department of Natural Resources-Soil and Water Program

**Missouri Department of Natural Resources-Solid Waste Management
Program**

Missouri Department of Transportation

Missouri Forest Products Association

Missouri Native Plant Society

Missouri Office of Public Counsel

Missouri Oil Council

Missouri Propane Gas Association

Missouri Public Service Commission

Missouri Public Utility Alliance

National Biological Service

Parkway School District

Sierra Club – Ozark Chapter

Springfield City Utilities

Sustainable St. Louis

University of Missouri-Columbia, College of Engineering

University of Missouri-Columbia, Cooperative Extension

University of Missouri-Columbia, Department of Agricultural Economics

University of Missouri-Columbia, Environmental Studies

University of Missouri-Columbia, School of Atmospheric Science

Washington University, School of Engineering

University of Missouri-Columbia, School of Natural Resources

Wheeler Medical Laboratories

Comments



July 12,2002

TO: MO Dept. of Natural Resources Energy Center
FROM: Winifred Colwiti. Energy issues Director. LWVMO
RE: LWVMO Comments on GHG Phase 3 Report

This report provides Missouri citizens with excellent, well-researched information on the sources and amounts of Missouri's greenhouse gases, their relationship to global warming, and effective actions to mitigate GHG emissions.

Among the many significant messages in this important document, three particularly stand out:

- * Energy use is the primary source of Missouri's GHGs and other air pollutants, with coal-fired electric generation being the single most important source. Therefore, strategies which improve energy efficiency and increase reliance on clean, alternative and renewable energy sources deserve priority attention.

- * A variety of specific initiatives to reduce GHGs, described in detail in this report, could be enacted or Implemented voluntarily to achieve significant GHG reductions in electric generation, buildings, transportation and agriculture. Progress will require active support from state and local government as well as the private sectors.

- * Most GHG reduction strategies will have multiple benefits. Including improved environmental quality, Increased economic production, and enhanced energy security. Therefore, GHG reduction is a sound policy.

Increased energy efficiency and reliance on renewable energy sources have been key elements of the national League of Women Voters' energy policy since 1978 in recognition of their economic and environmental benefits. The serious implications of the Impact of GHGs on global warming only add to the urgency to garner public support for effective action on the part of individuals, business and public entities.

We agree with the premise that priority should be given to strategies that achieve environmental goals and also provide GHG reductions. We also concur with the idea that initiatives designed to achieve long-term market transformation, such as incentives to purchase highly energy efficient appliances, should receive high priority.

The chapter on Residential and Commercial Buildings raises some questions. The building sector. according to the report, has the "greatest potential reductions"; in Missouri "the commercial sector is the most rapidly growing in electric use". Yet the only proposed Initiatives for commercial buildings relate to hospitals: most policy options in this section relate to residential buildings.

We see the need for the state to take the lead in raising public awareness about MO's GHGs and urge that a major energy conference be held In the near future.

Laclede Gas Company

July 24, 2002

Ms. Brenda Wilbers (via email)
Outreach and Assistance Center/Energy Center
Missouri Department of Natural Resources
P.O. Box 176
Jefferson City, MO 65102

Dear Ms. Wilbers:

Thank you for the opportunity to comment on the Missouri Greenhouse Gas Emissions Action Options Report. This report is more than a greenhouse gas reduction policy guideline. It presents potential ways to reduce multiple emissions, increase efficiency and increase the reliability of our energy supply. Our comments are as follows:

Electric Generation

- Successful distributed generation (DG) installations are needed for the environmental and reliability benefits of these systems to be realized. Two major barriers to new DG installations are interconnection and permitting.
- Output-based emissions standards with allowance for offsetting of "grid-averaged" central power plant emissions would more accurately allocate costs to emissions than the current input-based method with site boundaries. Pre-certification of equipment could streamline the development process and remove the uncertainty from the permitting process.
- Appendix I does not include all non-utility generators in our service territory

Buildings

- Energy consumption in Btu's and energy efficiency can be calculated on a site or source basis. Source-based metrics realistically reflect the full environmental effects of energy consumption. Therefore energy ratings systems, labeling standards, minimum efficiency requirements and model energy codes based on source energy metrics will provide the greatest environmental benefits.

Transportation

- Source-based emissions as a measure for comparing transportation sector options also most realistically reflect the environmental effects and therefore have the most potential for achieving environmental benefits.

We would be happy to provide a copy of a presentation given to the Missouri Energy Policy Task Force last year that explains some of these ideas in more detail. We would be interested in participating further with the State of Missouri on these issues.

Sincerely,

Beth Burka, P. E.
Mgr., Power Systems
Laclede Gas Company
314-342-0769

